HN/2

MENTAL HEALTH SERVICE SYSTEM REPORTS

Operations Research and the Mental Health Service System

Volume II
Critical Review and Annotated Bibliography

HE 20.8110/2:

READEX FICHE best copy available

MENTAL HEALTH SERVICE SYSTEM REPORTS

Operations Research and the Mental Health Service System

Volume II
Critical Review and Annotated Bibliography

Edited by

Larry G. Kessler, Sc.D.
Statistician

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Alcohol, Drug Abuse, and Mental Health Administration

National Institute of Mental Health
Division of Biometry and Epidemiology
5600 Fishers Lane
Rockville, Maryland

All material appearing in this volume is in the public domain and may be reproduced or copied without permission from the Institute or the authors. Citation of the source is appreciated.

Suggested Citation

National Institute of Mental Health, Series HN No. 2, Operations Research and the Mental Health Service System, Volume II, Critical Review and Annotated Bibliography. DHHS Publication No. (ADM) 80–1019, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, 1981.

DHHS Publication No. (ADM) 81–1019
Printed 1981

CONTENTS

Page

Preface.....v

Chapter 1

MENTAL HEALTH SERVICE SYSTEMS RESEARCH: THE NIMH PERSPECTIVE
Carl A. Taube, Larry G. Kessler, and Darrel A. Regier

I. Introduction.....1
II. Why Mental Health Service Systems Research.....1
III. Meeting Topics.....3
IV. Mental Health Initiatives.....4
V. Conclusions.....5

REFERENCES.....6

Chapter 2

OPERATIONS RESEARCH IN MENTAL HEALTH SERVICE SYSTEMS: CRITICAL REVIEW AND ANNOTATED BIBLIOGRAPHY
Jack E. Scott

I. Introduction.....7
A. Rationale for Critical Review and Annotated Bibliography.....7
B. Definitions of Operations Research.....9
C. Methodology of Critical Review and Annotated Bibliography.....13

II. Critical Review.....15
A. Program Evaluation.....15
1. Introduction.....15
2. Systems Analysis.....15
3. Systems Dynamics Modeling.....17
4. Stochastic Modeling.....19
5. Mathematical Programing Models.....21
6. Conclusions.....23

B. Analysis of Need and Demand for Mental Health Care.....24
1. Introduction.....24
2. Models of the Prevalence of Chronic Disease.....24
3. Length of Stay (LOS) as a Stochastic Process.....25
4. Models of the Utilization of Mental Health Services.....26
5. Forecasting the Demand for Services: Psychiatric Bed Requirements.....28
6. Summary.....28

Page

C. Resource Allocation.....30
1. Introduction.....30
2. Mental Health staffing in a State Hospital.....30
3. Selection of Optimal Training Programs for Mentally Retarded Patients.....32
4. Financial Planning Models.....32
5. Summary.....33

D. Author-Date References.....35

III. Annotated Bibliography.....38
A. Program Evaluation.....38
B. Analysis of Need and Demand for Mental Health Care.....46
C. Resource Allocation.....53
D. Miscellaneous Published Articles.....56
E. Author Index to Annotations.....63

PREFACE

The field of health services research first emerged as a serious discipline among the policy sciences during the late 1950s. This development was paralleled by the emergence of the first studies on health operations research during the same period. Applications of operations research methods to the problems of the mental health service system are even more recent; the first published studies did not appear until the late 1960s. In 1970, the National Institute of Mental Health published a handbook on the "Application of Operations Research to the Management of Mental Health Systems." The publication, now out of print, contained a variety of suggestions for the application of operations research methodologies to the problems of the mental health service system. With that publication as a stimulus, researchers began to examine the mental health services system from an operations research perspective. These two volumes provide an assessment of the contributions made by such studies and the potential of future studies in furthering our understanding of this increasingly complex health care system.

Volume I represents the report of an Ad Hoc Advisory Group on the state of the art and the prospects for future research. Volume II consists of two papers and an annotated bibliography of the literature on mental health operations research. The first paper assesses the contributions of operations research to mental health services research from the perspective of the National Institute of Mental Health as a funding and program-development agency. The second paper presents a critical review of the mental health operations research literature; this review and the annotated bibliography were prepared by Jack E. Scott while employed as a summer intern at the Division of Biometry and Epidemiology, under the supervision of Larry G. Kessler, Sc.D. Mr. Scott's work served as an invaluable background paper for the participants of the Operations Research-Mental Health Service System conference reported in Volume I. We hope that this review and bibliography will serve to instruct those who examine the mental health service system from a quantitative perspective. We also wish to encourage the extension of the type of research described here to further knowledge of the mental health service system.

Darrel A. Regier, M.D., M.P.H.
Director
Division of Biometry and Epidemiology

blank page

Chapter 1.

MENTAL HEALTH SERVICE SYSTEMS RESEARCH: THE NIMH PERSPECTIVE

Carl A. Taube; Larry G. Kessler, Sc.D.; Darrel A. Regier, M.D., M.P.H.

I. INTRODUCTION

The mental health service system has become increasingly complex during the past decade. Changing relationships among types of patients, service providers, facilities, and financing mechanisms have produced a system of care that sometimes is so difficult to define that it has been termed a nonsystem. To further the understanding of the mental health service system, researchers have turned to a variety of scientific disciplines to develop a comprehensive view of the interactions of the system components.

A major priority of the Division of Biometry and Epidemiology (DBE) of the National Institute of Mental Health (NIMH) has been the study of this service system from a quantitative perspective. One discipline recently utilized in quantitative mental health studies is operations research (OR). Although operations research to date has contributed only in a limited way to a fuller understanding of the mental health service system, there appears to be great potential to enhance that understanding by applying the diverse techniques that this discipline offers.

In this context, the purposes of this paper are threefold:

1. To present the NIMH perspective on current mental health service system research

2. To summarize several major areas of concern to those of us in NIMH who believe OR may contribute substantively

3. To describe briefly several current NIMH mental health service research initiatives, particularly those of DBE, that we believe will be of considerable interest to the operations research community as well as to those interested in systematic assessments of the operation of the U.S. mental health service system.

II. WHY MENTAL HEALTH SERVICE SYSTEMS RESEARCH?

A 1979 study report on health services research published by the Institute of Medicine of the National Academy of Sciences opens as follows:

> A need for more knowledge about health services in the United States is becoming increasingly apparent to health care professionals, government officials, and the public. Management of the highly diverse and interdependent personnel, facilities, and technologies that constitute modern

> health care institutions requires information similar to that employed in other complex business enterprises. In addition, the growing involvement of government in the financing, planning, and regulation of health care has heightened the demand of government officials for knowledge to guide the formulation and implementation of policy and the desire of the public for more information about their health care and the political choices that affect it. [Emphasis added.]

In the area of mental health and related services, this need for knowledge was underscored with publication of the report by the President's Commission on Mental Health in early 1978. Specific recommendations of the report are targeted at broadening the base of knowledge in a variety of areas that can be loosely termed health systems research in mental health.

To assess agency efforts in this area, the Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA) convened a workgroup charged with conducting a comprehensive review of ADAMHA programs in epidemiology, health systems research, and health statistics and data systems. The workgroup completed its work in 1978 and issued a report citing several obstacles to the effective coordination of mental health services research activities at ADAMHA. The report also set forth the following six recommendations for subsequent research activities:

1. Each institute should increase the resources devoted to studying the cost and financing of care, with immediate priority being given to studies assessing utilization and cost of administrative services under current health insurance and projected national health insurance plans.

2. Studies should be conducted to compare epidemiological, or direct, indicators of need for alcoholism, drug abuse, and mental health (ADM) services with indirect measures of that need, such as community socio-demographic profiles used in area health services planning.

3. Additional studies should be initiated on the current and optimal division of responsibility between the general medical and the specialty ADM services sector for the care of patients or clients with ADM disorders and problems.

4. The relative effectiveness and efficiency of alternative ADM treatment settings (e.g., community mental health centers, private office practice, health maintenance organizations) should be studied, with priority given to studies in which outcome measures are applied to patient cohorts.

5. Factors that facilitate or deter the receipt of treatment by people with ADM disorders or problems should be specifically evaluated at all levels of health services research.

6. Manpower studies must be supported to relate data on the supply, distribution, and utilization of ADM service personnel to information on ADM service needs, staffing mix, staffing standards, organization financing, and practice incentives.

In response to the findings and recommendations of this workgroup, the Division of Biometry and Epidemiology initiated a research grant program in Mental Health Service Systems Research. Designed to enhance current understanding of the resources, structure, and functions of U.S. mental health service systems, this program is expected to provide information for developing and implementing policy affecting mental health services at the local, State, and Federal levels. Issues of particular importance include mental health service utilization patterns, costs and financing of mental health care, interactions with the general health care system, and the capacity of the present service system to meet the mental health needs of the Nation.

III. MEETING TOPICS

The decision of the DBE to hold a meeting of operations researchers to assess potential contributions of operations research methodologies in the mental health service systems was based on the workgroup recommendations. Current knowledge of the operation of the mental health services delivery system is fragmented, focusing on the components of the system rather than on the system as a whole. There is a large body of knowledge concerning operation of specific facilities, effectiveness of certain treatments or programs, and utilization of general health services and mental health services by patients with mental disorders. However, as the spectrum of mental health services in the United States changes rapidly to include a broader range of inpatient and outpatient therapeutic regimens, the complexity of examining the mental health service system has increased. Thus, complex modeling methodologies, such as those embodied under operations research, should be powerful techniques for examining the complex mental health service system and its interactions with health and other social service systems.

Considerable efforts have been made with statistical and operations research models in examining need, demand, and utilization of specific mental health services. Research results fit a variety of utilization models of mental health services, yet it remains to be shown whether the relationship between need, demand, and utilization can be approximated by the use of modeling techniques. Further, the potential impact of policy and programmatic changes in the mental health system need to be analyzed within this conceptual framework. It appears that OR can make significant contributions in developing needs assessment methodologies, in characterizing the relationships among need, demand, and utilization, and in examining issues related to productivity, capacity, and other indices of mental health service system functioning.

Program evaluation is the area most often addressed by operations researchers in the field of mental health. The basic question in program evaluation has always been, "How can we assess and understand the effectiveness of mental health services?" The role that operations research can play in

current program evaluations is significant. Current Federal and State mental health programs, such as the Community Support Program (CSP) and Bureau of Community Health Services (BCHS)-National Institute of Mental Health (NIMH) Linkage Initiative, take place in a dynamic environment with respect to other social service programs. It is important to evaluate such programs not only in light of the clients they serve directly, but also in view of their effects on the mental health service systems as a whole. Clearly, the BCHS-NIMH Linkage Initiative is inseparably intertwined with the health care and primary health care systems in the communities in which these programs are located. It is crucial for operations researchers to adopt a broad perspective on the evaluation of new mental health programs in light of the programs' effects on the patients they serve, the populations from which these patients derive, and other social service programs in their environment.

One of the critical problems facing U.S. health care systems, including those for mental health, is the efficient allocation of resources. U.S. expenditures for mental health care have increased dramatically in the past several decades, particularly for outpatient services. Increases in both the proportion and the absolute number of patients whose mental disorders require large amounts of resources to treat will certainly increase the burden upon decisionmakers to make effective and efficient resource allocation decisions in the area of mental health services. Improved understanding of how the mental health service system responds to constraints upon resources and how those constraints affect the delivery of service to various populations is badly needed.

Outside the health care field, operations research methodologies are well known for their successful application in assisting decisionmakers in resource allocation. However, caution must be exercised in new applications of previously successful modeling methods. Operations researchers will need to form research teams with mental health clinicians and administrators so that their techniques can be enhanced by including an appreciation of historical and political perspectives relevant to resource allocation.

Finally, the mental health system interacts directly with a variety of other human service systems, including the general health care system, the criminal justice system, and the social service system. The information needed to understand the complex interactions among large systems is fragmented and extremely limited. Only relatively large efforts to examine these interactions can characterize them adequately. Research in this area could delineate the boundaries of the mental health care delivery system and define the impact of other major systems on the mental health care system.

IV. MENTAL HEALTH INITIATIVES

The DBE currently supports several initiatives of concern to operations researchers interested in the mental health service system. The newest and most extensive effort is the Epidemiologic Catchment Area (ECA) program in the division's Center for Epidemiologic Studies. The ECA program is designed to produce estimates of incidence and prevalence of mental disorders in U.S. communities. The program will also produce data concerning the epidemiology

of mental disorders in institutionalized populations and use of inpatient and outpatient health services as well as mental health services in relation to mental disorders. On successive waves during the course of the study, standard psychiatric interviews will yield research quality diagnoses of mental disorders.

Five ECA programs have been funded thus far. Yale University, The Johns Hopkins University, Washington University at St. Louis, Duke University, and University of California at Los Angeles, will be active research centers that could serve as foundations for mental health "modeling environments," a term suggested at the OR meeting.

In addition, DBE's Survey and Reports Branch is initiating a large panel survey of a cohort of patients who use the community mental health centers system. The study should provide accurate data on a variety of services used by patients with mental disorders. The Applied Biometrics Research Branch has a long history of studying the relationship between the general health care system and the mental health care system. The Primary Care Research Section is continuing those efforts by assessing the prevalence of mental disorders in the primary care sector and the management of those patients in relation to their use of services in both the general health and the mental health service systems.

Finally, several major program evaluation efforts are under way. The first of these is the evaluation of a major new NIMH initiative, the Community Support Program (CSP). This program is designed to provide health and social services for recently deinstitutionalized patients. Another evaluation effort is directed toward the BCHS-NIMH Linkage Initiative of 1978. This program is designed to link the primary health care system with the community mental health center system at the local level.

V. CONCLUSIONS

In summary, we seek to encourage a systematic assessment of the state of operations research as applied to the mental health services system and its problems. To that end, we have begun a three-phase process. The first phase, a critical review and annotated bibliography of OR applications in mental health, appears in this volume. The second phase, a series of papers presented at a meeting of prominent health operations researchers, is presented in Volume I of this series. In the third phase, we hope to stimulate researchers to continue the successful OR work that has only too recently begun. We also hope to encourage individuals in a variety of fields related to mental health services research to participate in collaborative efforts with individuals knowledgeable about OR methodologies. This collaboration should lead to a better understanding of the mental health service system.

REFERENCE

Health Services Research: Report of a study. Institute of Medicine, National Academy of Sciences, Washington, D.C., 1979.

Chapter 2.

OPERATIONS RESEARCH IN MENTAL HEALTH SERVICE SYSTEMS: CRITICAL REVIEW AND ANNOTATED BIBLIOGRAPHY

Jack E. Scott

Applied Biometrics Research Branch, Division of Biometry and Epidemiology, National Institute of Mental Health*

I. INTRODUCTION

A. Rationale for Critical Review and Annotated Bibliography

In 1978, the President's Commission on Mental Health noted that

> ...Adequate planning cannot be accomplished without reliable information - long term epidemiological and survey research necessary to understand the incidence and scope of mental disorders in this country. The need for more precise demographic and socioeconomic data is urgent if we are to understand and meet the different needs which exist in our society. Data to determine the availability and utilization of services are also insufficient. Without such data, it is difficult to assess needs or plan for and deliver services. (1)**

In response to the President's Commission's identification of this need, the Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA) convened four workgroups that same year to assess the agency's activities in four key policy-related areas. These areas were treated assessment research, manpower and training, prevention activities, and epidemiology, health services research, and statistics/data systems. The Workgroup on Epidemiology, Health Services Research and Statistics/Data Systems (2), focused on health systems research rather than the entire field of health services research.

Health systems research, as defined by the workgroup, includes aspects of epidemiology, demography, economics, and operations research. Functionally, health systems research incorporates four types of studies:

1. Assessment of need for health services;
2. Assessment of the supply of health resources;
3. Assessment of costs and financing of care; and
4. Systems analysis.

---

* Currently of the Division of Operations Research, The Johns Hopkins University School of Hygiene and Public Health.

** To distinguish text reference from annotated reference, two types of citations are used in this paper. Footnote numbers refer to the reference list at the end of the critical review. Author-date references correspond to citations listed in alphabetical order in each corresponding section of the annotated bibliography. The bibliography, which deals with applications, concludes the paper.

Because these types of studies frequently involve more than one discipline, the disciplines mentioned above appear to overlap.

As part of this ongoing assessment effort, the Division of Biometry and Epidemiology sponsored a project to assess the contributions of organizational sociology, economics, and operations research to mental health systems research. The operations research phase of this effort has been designed to achieve two broad objectives:

1. To catalog and critically assess past operations research applications in mental health systems research; and

2. To recommend additional areas within mental health systems research to which operations research might profitably contribute in the future.

Several efforts were made in the past to review operations research work in the health services field. Stimson and Stimson (3) reviewed operations research (OR) applications in general hospital settings in 1972. Shuman, Speas, and Young (4) provided an extensive critical appraisal of operations research in health care as of 1975, their book was organized around operations research techniques but includes two excellent sections appraising health OR from the decisionmaker's and the researcher's perspectives.

Fries (5, 6) produced two bibliographies of health OR articles appearing in journals through January 1978. As we go to press, he has listed a total of 352 references (not annotated). His bibliographies are organized by area of application rather than by technique. Fries uses 15 general categories in his classification of the health OR literature. These categories are:

General and introductory;
Health status;
Health planning and program evaluation;
Forecasting demand;
Hospital location;
Ambulance requirements and deployment;
Hospital occupancy - bed complement;
Hospital occupancy - elective admissions;
Special facilities - size and scheduling;
Staffing;
Appointment systems;
Hospital inventories;
Blood banking;
Examination scheduling; and
Miscellaneous.

Articles relevant to more than one category are cross referenced.

To date, no general reviews of the mental health/operations research literature have been published. Operations research applications to the mental health system appear to be a relatively recent phenomenon; the earliest published studies that have been found date back to the late 1960s, and the bulk of these were conducted during the past 8 years. There is a need to

examine these applications, both to review how operations research in mental health has been applied and to determine what directions it can and should take in the future.

B. Definitions of Operations Research

Operations research (OR) initially emerged through the activities of interdisciplinary teams of scientists employed by the governments of Great Britain and the United States during World War II. Since those early days, OR has taken a scientific, interdisciplinary approach to problems involving decisionmaking within complex organizations and social systems. Efforts to define operations research in a manner that satisfies its diverse range of practitioners have met with considerable difficulty.

Although the OR literature includes many definitions of operations research, these definitions can generally be classified as management-oriented or science-oriented in scope. Some examples of each may clarify the meaning of operations research as it is professed and practiced.

In 1971, the Committee on Professional Standards, Operations Research Society of America (ORSA), defined operations research as

> . . . a science that is devoted to describing, understanding and predicting the behavior of man-machine systems operating in organizational environments. (7)

Many practitioners view this definition as too narrow. Churchman defines OR as ". . the securing of improvement in social systems by means of scientific methods" (8) which conveys a more management-oriented approach. Duncan and Curnow define OR more broadly as ". . . the activity of tackling management or organizational problems in which there is a substantial quantitative component" (9).

A broader definition is presented by Halpert et al.:

> Operations Research (OR) is the name given to a group of techniques that can be used to help solve problems encountered in human organizations and systems. . . . Through the use of appropriate quantitative measures, OR attempts to trade off advantages against disadvantages in order to arrive at an optimal solution to a problem under a given set of circumstances. It is an effort to substitute analytic processes for hunch and "seat of the pants" procedures in administrative decision-making (10).

Although these definitions vary in scope, they share a common management orientation. Much OR work is carried out in the form of specific projects conducted for a particular component of the management of an organization. Much of this work is oriented toward discovering a specific, practical solution to a specified problem. In this sense, the OR practitioner functions as a troubleshooter for the management team.

Critics of the management orientation as a definition for the field as a whole argue that acceptance of a purely management orientation would result in little development of operations research as a scientific discipline. Yet, attempts to define OR as science have not been entirely successful either. Ackoff (11, 12) argued for the conceptualization of operations research as a science studying a particular class of phenomena: operations within oranizations. He constructed a fairly rigorous definition for the concept of operations (12) and has asserted that the category of operations within organizations represents a unique class of phenomena. Beer, however, contends that operations research is not a distinct science, but a subset of scientific method appropriate to the analysis of a particular class of problems:

> Operations research is the attack of modern science on problems of likelihood (accepting mischance) which arise in the management and control of men and machines, material and money in their natural environment. Its special technique is to invent a strategy of control by measuring, comparing and predicting probable behavior through a scientific model of a situation. (13).

Operations research can also be defined by its technologies for problem solution. One technique often seen in the application of operations research consists of the scientific, quantitative study of organizational and systems problems that can be formulated as follows:

Maximize (or minimize) $C_k = f(X_n, Y_m)$ (1)

Subject to:

$g(X_n) = 0$ (2)

$h(Y_m) = 0$ (3)

Where

f, g, and h represent functional operations;
$\underline{C}$ is the set of objective fuctions (statements about desired outcomes or outputs);
$\underline{X}$ is the set of variables under control or manipulable by management;
$\underline{Y}$ is the set of variables not under such control by management; and
k, n, and m are counters.

The first equation is called the objective function and is the key to the solution of the problem. In complex problems, there may be several objective functions. Further, these may not all be optimized at the same time, and some trade-offs have to be made. The second and third equations are called

constraints and represent boundaries of individual variables and various weighted combinations of variables. The constraint set is what limits the objective function to "reasonable" values.

The above approach is representative of what is termed mathematical programing, an important set of techniques within the field of operations research. In general, such techniques seek to allocate scarce resources among competing activities in an optimal manner, subject to various constraints affecting both the activities and the use of the resources.

A number of other approaches find frequent use in operations research applications. Queuing theory is a branch of mathematics that studies waiting lines. Queuing theory provides a useful approach to the problem of balancing the cost of providing a service with the costs of waiting for that service. The application of queuing theory techniques does not solve such problems directly, but does provide information that can be used in finding the solution (e.g., determining the average waiting time to receive service, or the probability that the time until service will exceed a given duration). Queuing theory has been used to model the flow of patients through hospital emergency rooms (14) and other hospital departments.

Another type of probabilistic model is the Markov chain. A Markov chain is a stochastic process (i.e., a probabilistic sequence of events) having the property that the probability of moving from a present state to the next state is independent of the past history of the sequence. Markov chains have been used to model a variety of empirical processes in the health services system, including coronary patient recovery (15), health service planning (16), and hospital admissions scheduling (17).

A fourth major technique frequently used in operations research is simulation, which models the interactions of all the predictably behaving components of a system over time. By changing the relationships among components or by varying the data fed into the models, it is possible to explore the impact of various changes of the system. Some general examples in the health services literature include a simulation of a health maintenance organization (18) and a model of dental manpower requirements (19).

These techniques represent a few of the more commonly encountered OR techniques. Examples of these and other types of applications are presented in the critial review and annotated bibliography in this volume.

Regardless of the technique employed, there is a general consensus (10,11,20) about the basic operations research approach to the problems it studies. Halpert et al. (10) provided an excellent statement of this approach, which they broke down into the following six steps:

1. Defining the problem;
2. Constructing the model;
3. Deriving a solution from the model;
4. Testing the model;
5. Implementing the solution; and
6. Monitoring the effects of changes on the actual operations of the system

Luckman and Stringer note that ". . . an essential question to be answered prior to any OR study is 'Who has the problem' -- since it is his scope for action that will define the boundaries and content of the study" (20). Halpert et al. (10) note that defining the problem includes identifying the objectives of the organization and the various alternative courses of action available to the decisionmaker. Another important phase of this step is the selection of a measure that can be used to determine the relative efficiencies of the various alternatives in terms of quality and costs.

Once the problem has been suitably defined, work can begin to construct an appropriate model of the situation. Halpert et al. (10) describe three types of models: Iconic something that looks like what it represents such as a scale model of a ship; analog (charts or graphs); and analytic, or mathematical models. The last are by far the most common in operations research. Ackoff (11) notes that the third model constitutes an expression of ". . . the effectiveness of the system as a function of a set of variables at least one of which is subject to control." The complexity of analytic models frequently requires the use of a computer for solution.

When the model has been constructed, the OR practitioner has assembled a mathematical description of the relationships among the controllable and non-controllable variables and outcome measures operative in his problem. The OR practitioner then seeks to derive a solution from the model. Sometimes no numerical solution can be obtained, but new insights into the dynamics of the problem emerge. Often it is possible to obtain a definite numerical solution.

At this stage, it is important to test the model. This may be accomplished in several ways. If data are available, the predictions of the model may be compared against the actual performance of the modeled system. Sensitivity analysis (i.e., systematic alteration of parameters within the model to ascertain the sensitivity of the model to such change) represents another means of testing the model.

Perhaps the most demanding test of a model and the solutions derived from it is implementation of these solutions. During the implementation phase, it is very important to be able to monitor the system effectively to determine the actual effects of changes in operations. This monitoring permits the practitioner to suggest any necessary further modifications.

We have seen that operations research consists of a scientific, largely mathematical approach, to a class of problems that arise within complex organizations and social systems. This approach relies heavily upon the specification and construction of analytic models of the problems under study. The scientific study of the theory underlying these analytical models constitutes the science of operations research. The art of their application and implementation in specific organizational contexts constitutes the applied, management-oriented side of OR. It is important to recognize that

both sides of OR are necessary, for the theoretical discoveries of today often result in tomorrow's application, and the wider class of applications develop natural and important problems for the theoretician.

C. Methodology of Critical Review and Annotated Bibliography

In constructing this review and bibliography, we chose to restrict our efforts primarily to those papers and studies that have appeared in the published literature. Although a number of factors shaped this decision (e.g., time constraint, accessibility, etc.), we also felt that such published reports represent an important source for the mental health professional community's impressions of operations research as a discipline. However, we included also three unpublished doctoral dissertations that were particularly relevant and accessible. Thus, although these operations research reports may represent only a small fraction of the actual work conducted in this area, it is an important fraction worthy of examination.

The articles selected for the review were located by means of an exhaustive search through a variety of operations research, management science, mental health, and behavioral sciences journals (see table 1). In selecting these articles, we decided to use a broad definition embodying both the management- and science-oriented approaches to determine what constitutes an operations research application. Using this criterion, we located 71 articles that were issued during the past 13 years (1967-80) and that we believe are representative of the contributions of operations research to the study of mental health service systems.

In classifying these articles, we attempted to follow the classification scheme used by Fries. We found, however, that the mental health/operations research literature necessitated deletion of some categories (e.g., blood banking, inventory control, facility location) and the inclusion of others (alcohol and drug abuse, mental retardation). Because of the small number of articles in several categories, we collapsed the classifications into three general headings: Program evaluation; analysis of need and demand for mental health services; and resource allocation. Although these categories display some degree of overlap, the general headings do reflect important areas for applications of OR to the mental health services system.

The remainder of this paper is structured in the following manner. A review of operations research applications in mental health is presented in three sections (program evaluation, analysis of need and demand for mental health services, and resource allocation); the primary purpose is to demonstrate some of the range of mental health issues to which operations research can be relevant, and to highlight some of these applications. An annotated bibliography of these applications concludes the paper.

Table 1.
Frequency of OR reports (1967-80), by source, in annotated bibliography

Source	Number of Articles
Administration in Mental Health	6
American Journal of Mental Deficiency	2
American Journal of Psychiatry	3
American Journal of Public Health	1
Behavioral Science	3
Canadian Journal of Public Health	1
Community Mental Health Journal	3
Computers and Biomedical Research	2
Evaluation	3
Health Services Research	2
Inquiry	3
International Journal of Mental Health	2
International Journal of Social Psychiatry	2
Journal of the American Institute of Planners	1
Journal of Chronic Diseases	2
Journal of Mathematical Sociology	2
Journal of Medical Systems	1
Journal of Mental Health Administration	2
Journal of Nervous and Mental Disease	1
Journal of Psychiatric Nursing and Mental Health Services	1
The Journal of School Health	1
Journal of Studies on Alcohol	2
Management Sciences	2
Maryland State Medical Journal	1
Operations Research	4
Policy Sciences	3
Psychiatry	1
Psychological Reports	1
Socio-Economic Planning Sciences	1
Unpublished doctoral dissertations	3
Other--books, Government publications	9
	71

II. CRITICAL REVIEW

A. Program Evaluation

1. Introduction

Program evaluation has been increasingly important within the mental health services system. The Community Mental Health Centers Amendments of 1975 (Public Law 94-63) require that community mental health centers perform program evaluation, and several States have instituted their own requirements for program evaluation within the mental health system (e.g., Massachusetts and California).

Several approaches are commonly used in conducting mental health program evaluation. These include what Goldberg (21) describes as subjective appraisals (judgments made by experienced professionals through on-site visits, peer review studies, and case studies), monitoring approaches (audits and inspections), and budgetary systems, such as the Program Planning and Budgeting System (PPBS) (22), and evaluation research models. These models include goal attainment approaches and "testing" models, including operations research approaches.

In this section, we focus on operations research models and their con tributions to program evaluation in the mental health services system. Specifically, we consider the contributions of systems analysis, systems dynamics modeling, stochastic modeling, and mathematical programing (including assignment models and transportation models).

2. Systems Analysis

Systems analysis can be broadly defined as a method of approaching problems from all conceivable sides, weighing costs and foreseeable consequences of alternatives, and choosing a best solution. Systems analysis approaches in mental health program evaluation have frequently applied organizational sociology and economics concepts to the analysis of mental health systems.

General systems theory applies a number of sociological concepts (differentiation, integration, etc.) to the analysis of systems (frequently defined as sets of interacting elements). Applications of general systems theory in community mental health have been reviewed by Kilburg (23), who notes that the systems perspective has provided a substantial conceptual foundation for a variety of community mental health activities. However, Kilburg also reports that he ". . . could find no published data on actual implementation of general systems theory in the daily operations of the various levels of the mental health system" (24).

An example of the systems approach applied to program evaluation is presented by Mittenthal (1976) in an evaluation of the DHEW Services Integration Targets of Opportunity (SITO) program. The SITO program consisted of a number of projects across the country designed to integrate the planning, management, and provision of human services (i.e., welfare, mental health, rehabilitation, and educational programs). Because the projects had not developed performance measures and data that would permit

traditional evaluation, a descriptive system analysis approach was employed to determine the extent to which each project (system) possessed the elements of an idealized model of a productive and accountable human services system.

The dimensions examined in this analysis included mechanisms of system governance, roles of the system manager, service delivery system, performance specifications of the system, auditing mechanisms for identifying the actual effects achieved, and funding mechanisms. The analysis identified effective models of system governance and called attention to several problem areas within the various projects, such as collection of insufficient data on needs assessment, system performance, and cost measures; ineffective design of management information systems; and role confusion and ambiguity among system agents (case managers, service brokers, etc.).

Murrell (1971) presents an open systems conceptualization of the process of patient change in psychotherapy, integrating concepts and findings from social ecology, general systems theory, cybernetics, and information theory. In this model, patient change occurs as an interaction between the therapist-patient system and the patient and his social support system (family and friends). Pathology is viewed as a positive feedback phenomenon, in which a change in A results in a change in B, which in turn changes A--the vicious circle.

To initiate change in the patient, the therapist must introduce negative feedback (information or experiences that do not increase B or even act to reduce it) within a range of patient tolerance for such change. Once change has been initiated, the crucial determinant of its maintenance is the accepting or rejecting response of the patient's social support system to this input. An interesting aspect of this model of patient change is that it includes the possibility of change in the therapist as well as in the patient. Thus, this approach could be used as a means of studying "burnout" in mental health professionals as well as the efficacy of therapy.

Systems analysis frequently makes use of economics concepts as well as those from sociology. For example, Hutcheson and Krause (1969) present an input-output model for mental health based upon the "inter-industry" approach developed by the economist Leontief. In the inter-industry analysis, a matrix is constructed displaying the dollar value of material goods or resources produced and consumed by the given group of industries; that is, those in a common geographic location or otherwise related by membership in the same sector of the overall economy. Each cell entry reflects a ratio of resources produced to those consumed for a specific pair of industries. The Hutcheson and Krause model similarly divides a community into several sectors (household, nonprofit organization, for-profit organization, the wider environment) and examines the production and consumption of units of time among the various sector combinations.

The problems with developing a mental health analogy to the Leontief approach to input-output analysis are, as the authors point out, the ambiguity as to who the consumers and producers are and what the goal of the system is. If implemented, however, the model can function as a planning tool and, when baseline data are established, as an evaluation tool for assessing the impact of mental health programs on community activities.

Another type of model frequently associated with systems analysis is the network (patient) flow model. This model permits the study of the flow of patients through a network of treatment services, as illustrated in Burgess et al. (1974). This study presented an analysis of patient flow through the services of a community mental health center, focusing on the presence of cycles (return paths through two or more service nodes) as a measure of service ineffectiveness. Their analysis of cycles showed that the patients most "difficult to treat" had the greatest number of cycles and that patients with one or more hospitalizations in a State hospital facility were more likely to cycle within the system than were other patient groups.

Burgess et al. suggest that, in addition to the analysis of cycles, patient-flow models can be used to address a variety of other evaluative concerns. Among these are the identification of client pathways that promote the longest duration of independent community adjustment, evaluation of the impact of a consolidation of treatment services on community adjustment, assessment of the costs of various forms of treatment, and the performance of utilization review studies. Mittenthal (1976) suggests that the routine documentation of client pathways through a treatment system provides a measure of program and system accountability. Although a network approach is deterministic and thus may not capture all the dynamics of patient movement, its intuitive formulation makes it more easily accessible to program evaluators than some of the more complex mathematical models.

The quality and availability of appropriate data can hinder or help the use of patient-flow models. Ogurzsoff et al. (1976) reported that they were unable to construct a patient-flow model of patients seeking alcoholism treatment services from nine independent agencies in an Ontario community. Nonstandard patient codings and a lack of documentation of referrals and followup procedures among the treatment agencies were cited as reasons for this failure.

3. Systems Dynamics Modeling

Systems dynamics modeling developed from the efforts of Jay W. Forrester and a team of scientists at the Massachusetts Institute of Technology during the 1960s. Forrester describes the systems dynamics model as ". . . a statement of system structure. It contains the assumptions being made about the system" (25). He further notes that

> This approach to the dynamics of social systems differs in two important ways from common practice in social sciences and government. There seems to be a common attitude that the major difficulty is shortage of information and data. Once data is collected, people then feel confident in interpreting the implications. I differ on both of these attitudes. The problem is not shortgage of data but rather our inability to perceive the consequences of the information we already possess. The systems dynamics approach starts with the concepts and information on which people are already acting. Generally these are sufficient. The available perceptions are then assembled in a computer model which can show the consequences of the well-known and properly perceived parts of the systems. Generally the consequences are unexpected (26).

Systems dynamics models can be characterized by the presence of one or more feedback loops. These loops represent positive or negative feedback as described earlier. In this manner, a systems dynamics model can express nonlinear causality among its various elements, theoretically permitting a more accurate model of the real world.

Systems dynamics models in mental health have included models of the mental hospitalization process (Hertzman and Levin 1974a; 1974b), the treatment dropout process in a community mental health center (Levin and Roberts 1976), and the evolution of a "narcotics problem" in a community (Levin et al. 1972). The ability to apply sensitivity analysis to these models (systematic alteration of parameters of interest to determine the effect upon other system parameters and upon the system as a whole) increases their applicability to program evaluation. Hertzman and Levin (1974a; 1974b) present a series of systems dynamics simulations of the hospitalization process. Components of the model include a general hospital with two inpatient psychiatric wards and a psychiatric emergency room, and a State hospital. One of the two general inpatient psychiatric wards receives patients from a community mental health center, and the other accepts non-CMHC patients screened by the psychiatric emergency room. Patients are admitted to the State hospital only through the two general hospital wards; however, the State hospital receives patients from other sources as well as from the general hospital-CMHC subsystem.

In both studies, workload (perceived time and effort devoted to patient care by staff), morale (state of relative staff satisfaction with the work being done), and admission and discharge data are analyzed to explore the effect of fluctuations in admission and discharge rates on workload and morale. Morale was assessed by means of a rating scale over a 70-day period.

The first study revealed a time lag between periods of peak admissions and periods of peak visits to the psychiatric emergency room. The second study used this finding to develop the synchrony ratio--a measure of system response to patient needs. Hertzman and Levin used the synchrony ratio as a measure of the degree to which admissions were proportional to emergency room visits. Together, the two studies suggested to the researchers that a vicious circle exists, in which

> . . . the perception of falling morale on the ward leads to early discharge of patients, the easiest antidote to the heavy workload which is causing the fall in morale. Morale initially rises, but discharges create increased capacity for new admissions. Since admissions require more work than discharges on old patients, workload becomes worse as a consequence, and eventually morale declines as well (Hertzman and Levin 1974b, p. 220).

Although the chain of events these authors describe may be accurate, causal inferences between these events probably cannot be made using their data.

Another systems dynamics study by Levin and Roberts (1976) models a community mental health center to study the phenomenon of dropouts from treatment. In this instance, the study uses two sets of simulations with the model to explore six parameters hypothesized to affect the dropout rate among patients with chronic psychiatric disability. These parameters are as follows: Treatment timetable (intensity of treatment required to restore functioning within a stated time period), staff expectation of treatment efficacy, criticality (staff willingness to allocate treatment resources based upon their assessment of the degree of crisis involved), the patient's standard of functioning, benefit from treatment expected by the patient, and habit.

The first set of simulations explores the interrelationships of these parameters under various conditions (e.g., exaggerated staff expectations of treatment efficacy, a delay in the treatment timetable, a combination of unstable standard of functioning and indifference toward benefit from treatment). A second set of simulations attempts to identify corrective strategies through increasing the patient's standard of functioning and enhancing the patient's initial level of expected benefit from treatment. The latter strategy is identified as an effective approach.

Levin et al. (1972) present a simulation of a community experiencing a narcotics addiction "epidemic," examining the responses of law enforcement and health personnel to this occurrence. The model is interesting for its attempts to specify the social conditions under which drug abuse treatment programs will be accepted as an appropriate community response to narcotic addiction.

4. Stochastic Modeling

In attempting to predict the future occurrence of an event of interest (recovery from mental illness, for example,) two general modeling approaches might be taken. If we are dealing with a large population and a clearly definable event, we may be able to assume that statistical fluctuations within the data are small enough to be ignored. Modeling approaches that make this general assumption are described as deterministic. However, if the group of individuals under consideration is small enough that chance fluctuations are appreciable, a stochastic modeling approach is usually preferable.

Bailey defines the stochastic modeling approach as follows:

> ...A model which specifies the complete joint probability distribution of the numbers of different kinds of individuals at each point in time would be a stochastic model, and the whole process, conceived as a continuous development in time would be called a stochastic process (or probability process) (27).

A specific type of stochastic process is the first-order Markov process, in which the future probability behavior of the process is uniquely determined once the state of the system at the present stage is given. Various types of Markov processes can be used to model this type of empirical phenomenon; the most widely used is the first-order Markov chain.

There have been several interesting applications of Markov chains in mental health program evaluation of programs for the mentally retarded.

Meredith (1974) evaluated four hospital programs for the mentally retarded at Pacific State Hospital in California, using a stationary Markov chain model to describe each program. The programs evaluated in the study were intensive training, behavior modification, day school, and a foster placement program; these were compared to the standard care regimen of the hospital.

Meredith used rating scales to measure ability levels for eight skill variables of interest. These ability levels were then used to define transition states in the model. The model assumes that the rating scale score for any given year depends only upon the score obtained in the previous year, and that the transition probabilities are constant over time.

Meredith used data obtained from a cohort of 615 profoundly and severely retarded children to calculate the transition probability matrix for each program. Costs per program per child were also available. Meredith found that transition probabilities associated with the behavior modification program were not significantly different from those associated with the standard care regimen. Further analysis of the transition matrices of the four programs over a 4-year period revealed that the primary value of the more expensive programs (intensive training ward and day school) lay in their maintenance of existing levels of ability rather than in the improvement of these levels. This surprising finding suggests a new dimension of program effectiveness to examine in subsequent studies. Qualifications must be placed on these results, because the data are based on a single transition and no attempts are made to verify empirically the assumptions of a model of this type.

Trinkl (1974) applied a constrained, value-weighted Markov chain in evaluating the impact of proposed budgetary changes in programs for the mentally retarded adult in Hawaii. Trinkl's model represents one of the first successful attempts to incorporate value judgments and constraints in a Markov chain to produce insights into preferred program choices. Trinkl identified 17 transition states based upon combinations of living circumstances, treatment requirements, and employment status and then subjectively evaluated the probabilities of making these transitions. The goals of the various programs were built into the model by a value-weighting procedure that weighted movement between various transition states.

Trinkl imposed constraints upon the model through the use of penalty costs incurred when patients had to accept a less-than-optimal placement. The analysis combined the achievable values for the various transition states based upon the value-weighting approach and the costs incurred in achieving these states. The similarity of this approach to a cost-benefit analysis, which measures benefit in nonmonetary units, is a strong advantage of Trinkl's formulation. One must be especially cautious, however, in interpreting a model so heavily dependent upon subjective estimates of transition probabilities and their value weights.

5. Mathematical Programing Models

Mathematical programing has generally been considered one of the central tools of operations research. Mathematical programing is a general term for a set of models and techniques that can be applied to problems concerned with the allocation of limited resources among competing activites or organizations in the most effective manner. In linear programing models, all mathematical functions are required to be linear functions. Integer linear programing adds the additional restriction that all decision variables must have integer values. Nonlinear programing relaxes the restriction on linear functions described above. Dynamic programing differs from linear programing in a number of ways (28) and is especially useful for problems that require making a sequence of interrelated decisions.

Shuman and Wolfe point out:

> Mathematical programming is the most emphasized analytical technique in academic operations research programs. It is usually attributed to be the one operations research approach that has been most profitably used in solving actual industrial problems. Nevertheless, in health applications, mathematical programming has not lived up to the expectations of practitioners, planners, and health administrators (29).

Since mathematical programing applications in mental health program evaluation are very recent, it is difficult to predict the extent to which their history will parallel the history of such applications in general health care.

Correa and Sangl (1977) present an important review of mathematical programing models, from linear programing through dynamic programing and probabilistic models, for planning drug abuse control programs. This is a significant review in several respects. Using parameters estimated from a review of the drug abuse literature, Correa and Sangl demonstrate the applicability of mathematical programing models to the development of control strategies for drug abuse. The potential application of programing models to program evaluation is discussed as well.

The problem of assigning elements of a set of resources to a series of activities is a special type of the general mathematical programing problem known as the assignment problem. One example of the assignment problem would be the assignment of a series of tasks to a group of individuals. Different costs might be associated with the assignment of any given task to two different individuals. The assignment problem is formulated in such a way that the objective then becomes the minimization of total costs, subject to the requirements that all tasks be assigned and that all individuals receive a task.

Wolpert and Wolpert (1976) recommend this approach for examining the impact of deinstitutionalization on community mental health services. They note that many released mental hospital patients find their way into the inner-city communities (either as a result of prior inner-city residency, or

drift). Wolpert and Wolpert suggest the use of an assignment model to evaluate the extent to which the observed social services dependency distributions of released hospital patients approximate an optimal distribution which maximizes favorable treatment outcomes. The model requires the existence of a classification of patients by diagnosis or symptoms, defined classes of treatment modalities, a set of treatment outcomes associated with the assignment of patients to all possible alternative facilities, and a set of costs attributable to each of the treatment facilities. Wolpert and Wolpert acknowledge that several elements do not yet exist, which highlights the need for future research. For the present, the assignment approach could provide a structure for subsequent analysis of the effects of deinstitutionalization of mental hospital patients and the decentralization of services.

Another special type of mathematical programing problem is transportation. In general formulation, the transportation problem concerns distribution of a commodity from a group of supply centers (sources) to a group of receiving centers (destinations) in a way that minimizes total distribution costs.

Muraco et al. (1977) combined a transportation model with an assignment model to evaluate the potential impact of decentralizing mental health services in Lucas County, Ohio, a medium-sized county with a population of 430,000 according to the 1970 census. The objective criterion employed in this analysis was accessibility to mental health services as measured by the minimization of client traveling expenses.

The authors measured demand for mental health services by comparison of several demand indicators and by social area analysis; that is, the statistical development of social indices of subpopulations located in a particular area derived by means of a factor or cluster analysis of demographic data from a geographically defined population (30). Both approaches revealed that the demand for mental health services in Lucas County is geographically concentrated.

The authors then formulated the problem as a multifacility, constrained transport problem. At the points where demand for services were geographically clustered, service centers were allocated. Service centers were required to maintain a demand load of at least 500 clients per year. An additional constraint prevented the assignment of two or more service centers to one geographic demand cluster.

Muraco et al. concluded that, given the concentration of demand for mental health services in Lucas County, further decentralization of services introduced only a modest reduction in overall client travel expenses while increasing the mental health system's expenses by a minimum of $150,000 per year for each new center added. They acknowledged, however, that the generalizability of these findings to other counties is sharply limited and that further study of the relationship of population size, demand for service, and decentralization of services is needed.

6. Summary

A variety of operations research perspectives have been presented. From these studies it is evident that mental health program evaluation has been and will continue to be an important focus for the application of operations research techniques. Much of the operations research activity in this area is very recent (within the past 5 years) and is still in the preliminary stages of development. For example, four of the five articles on systems analysis discussed in the section and listed in the annotated bibliography did not actually use data to implement their models. Certain modeling approaches, however, have emerged as especially applicable to mental health program evaluation. Among these, we would especially note network flow models, stochastic models, and systems dynamics models.

Network flow models appear promising as a routine tool for maintaining administrative control over the service delivery system. Burgess et al. (1974) suggested a variety of applications for these models; their applicability to studies of utilization review should be noted. However, as Ogurzsoff et al. (1976) caution, the quality of available data can sharply limit the use of network flow models.

The use of stochastic models in program evaluation is likely to expand in the future. The use of Markov chain models can be highly compatible with a cost-benefit approach (see Trinkl, 1974; Meredith, 1974), and the models appear to be useful with a variety of populations and program settings.

One problem encountered in the use of Markov chain models is that the transition probabilities generated from a particular program interacting with a particular population are unique, thus limiting the generalizability of findings. The extent to which these transition matrices vary across programs of the same type is not known. There is a clear need for further research on this question, and an additional need for such studies to be published.

Systems dynamics modeling continues to be controversial. There have been criticisms of the assumptions and structural characteristics of these models. Despite such criticism, system dynamics models can be useful in program evaluation. (See especially Levin and Roberts 1976.) More experience in the use of these models will reveal the extent to which these criticisms are justified. The use of interdisciplinary teams in formulating and applying systems dynamics models can provide a useful check on the appropriateness of the assumptions used in the model. (See Levin and Roberts 1976 for a discussion of this process.) A strong advantage of this general approach is its capacity for depicting different forms of causality within the same model.

B. Analysis of Need and Demand for Mental Health Care

1. Introduction

The studies considered in this section generally concern aspects of the utilization of mental health services (demand). At this time, little work has been conducted from an operations research perspective on the assessment of need for such services. Some recent non-mental-health epidemiological formulations making use of operations research perspectives are discussed briefly, because the issues raised in these studies possess some relevance for mental health service system research. Following this discussion, we present several probabilistic models of the length of patient stay in public mental hospitals and community mental health centers, and three utilization models of State mental hospitals, a community mental health center, and a statewide inpatient system.

2. Models of the Prevalence of Chronic Disease

Epidemiology represents a major approach to the measurement of need for health services. One of the more complex problems in general, and in psychiatric epidemiology in particular, is the determination of the prevalence of chronic mental disease. The general epidemiologic equation for prevalence can be written as

$$\text{Prevalence} = \text{Incidence} \cdot \text{Average Duration}$$

Measurement and definitional problems abound in each term of this equation. In applying this equation to chronic disease, for example, the terms prevalence and average duration become particularly difficult to define.

The concept of prevalence can be viewed from a variety of perspectives, depending upon the time-frame used and the population being discussed. This latter point bears some elaboration. We can speak of source prevalence (the prevalence of a disease in the total population, including those who receive treatment and those who do not) or treated prevalence (the prevalence of a disease as determined by the number of individuals who report to some type of health care facility, are diagnosed as having the disease, and receive health care treatment services for it). Source prevalence represents a measure of need, and treated prevalence can be used as a measure of demand. Thus, the relationship between these two forms of prevalence rates is important for planning purposes.

Mullooly and Oleinick (1975) attempted to analyze this specific relationship for chronic allergic diseases (asthma, hayfever, rhinitis, etc.). Using data generated from the computerized population and utilization records of the Kaiser Health Plan, they constructed a system of differential equations modeling the relationships of immigration rate (members joining the plan), emigration rate (members dropping out of the plan), diagnosis rate, remission rate, and time, to the overall cumulative, treated prevalence rate within the plan during the years 1967-1971. These equations were used to predict the equilibrium source prevalence rate for chronic allergic diseases within the membership of the Kaiser Health Plan.

The model was then tested against data from Tecumseh, Michigan, where survey data on source prevalence rates existed. The equilibrium source prevalence rates projected by the model were in close agreement with those obtained by survey.

An additional aspect of this model is its use of a diagnostic intensity parameter (the proportion of diseased, undiagnosed individuals who present to the clinic and are diagnosed per unit time). The authors note that this parameter is a composite of system accessibility and diagnostic accuracy, and could be used in evaluating various medical care systems.

Von Korff and Parker (1980) explore the dynamics of the prevalence of chronic episodic disease (schizophrenia). They argue that the traditional formulation of prevalence presented above is inappropriate for diseases that run an episodic course. Using a life table analysis of a cohort of schizophrenic patients admitted to State hospitals from Dutchess County, New York, during 1964-65, the authors formulate a Lifetime Sickday Proportion (LSP), expressed as LSP = Incidence · Average Episode Duration · Average Number of Episodes, which they offer as a more realistic estimate of prevalence. Through the use of 5-year followup data on this cohort, the authors model average episode duration with a mixed exponential probability function and the average number of episodes with a geometric probability function. Although the assumptions required by the use of these models may not be fully obtained in practice, the authors conclude that the models can and should be used as heuristic devices for characterizing the dynamics of chronic episodic diseases.

3. Length of Stay (LOS) as a Stochastic Process

Formulations of length of patient stay are important tools for the planning and administration of mental health care facilities. Eaton and Whitmore (1977) formulate length of stay as a stochastic process, in which health status is viewed as a function of time. They present a comparison of eight models (life table, exponential, mixed exponential, Pearson type XI, Wiebull, gamma, lognormal, and inverse Gaussian) fitted to data taken from the Maryland Psychiatric Case Register. The data were from a sample limited to patients diagnosed as schizophrenic and admitted for the first time to any inpatient facility in Maryland between 1961 and 1968 (n = 2,311). A quantile estimation technique is used to fit the models to the data, and goodness-of-fit is tested by a criterion of maximum absolute deviation of the estimated distribution from the observed distribution. The authors acknowledge that this criterion is affected by the quantiles selected for the estimation procedure.

Eaton and Whitmore obtain the best fit, as judged by their criterion, with the inverse Gaussian and lognormal models. They note that the inverse Gaussian model may be preferable to the lognormal model, because the parameters of the former are more readily interpreted. In particular, the process drift parameter, (b-a)/u, represents the propensity of the patient to get well, and could be used as a direct measure of the effectiveness of a treatment milieu and regimen. The authors indicate that an exact statistical test for zero drift in the inverse Gaussian model currently exists (see Seshadri and Shuster 1974, cited in Eaton and Whitmore 1977).

In a reexamination of the Eaton and Whitmore paper, Von Korff (1979) notes that the quantile estimation procedures used by Eaton and Whitmore are inefficient, and that their goodness-of-fit criterion is insensitive to the poor fit of the various models in the tail of a skewed distribution. Using a maximum likelihood method, he refits a mixed exponential model to the Eaton and Whitmore data, and tests goodness-of-fit using a chi-square analysis and the Eaton and Whitmore criterion. Von Korff then concludes that the mixed exponential model provides a fit to the data comparable to those Eaton and Whitmore report for the lognormal and inverse Gaussian models. Von Korff notes that none of these models can be regarded as a natural law of LOS for this sample.

Another approach to the analysis of length of stay is illustrated by Reuter and Von Korff (1980). They employ the hazard function (the discharge rate of persons who have remained in treatment for X time periods) to predict the accumulation of chronic, long-term patients in a community mental health center. Length of stay for 123 inpatients is estimated by the Weibull model. One of the parameters of this model is sensitive to increases and decreases in the distribution's hazard function.

Using a computer simulation to vary the parameters of the model, Reuter and Von Korff note that the hazard function for this sample decreases as LOS increases; as a result, the slope of the hazard function can provide a strong indicator of the eventual size of the long-term population in a CMHC. They further indicate that the accumulation of long-term patients tends toward a steady-state equilibrium. Systems that can be characterized by a decreasing hazard function require longer periods of time to reach equilibrium than do systems characterized by an increasing hazard function.

Fox and Kraemer (1971) note that the cumulative proportion of discharged patients rehospitalized one or more times over various time intervals is frequently used as a measure of the effectiveness of psychiatric hospital treatment. They present two stochastic models of the readmission rate based upon the mixed exponential distribution. The models embody contrasting assumptons: In model I, all patients require rehospitalization at some time, while model II assumes that a certain proportion of the patient population will not require rehospitalization. Data for admissions, discharges, and readmissions were obtained from a public mental hospital facility for an 18-month period. The models were fitted to the data by the maximum likelihood method. Model I predicts rehospitalization better for short periods of time, while model II provides better prediction for longer periods (goodness-of-fit criteria unspecified).

4. Models of the Utilization of Mental Health Services

Operations research approaches to modeling the utilization of mental health services have generally taken the form of Markovian models and systems dynamic approaches. These models can capture the sequential, dynamic process of utilization while reflecting the interdependency of mental health service subsystems. A few examples of these models are presented here; other examples can be found in the program evaluation section.

Reuter (1977) utilizes a semi-Markov chain model to describe the flow of patients among several service subsystems in a community mental health center. The advantage of such an approach is that a semi-Markov chain permits the modeling of length of stay in a state by a variety of probability distributions.

A critical aspect of the semi-Markov model is the first-order assumption that underlies its various states. The first-order assumption permits the model to capture the dynamics of the treatment process and identify the interdependency of the treatment subsystems:

> . . . In essence, if a unit is a first-order state, it is implied that the care provided in this state is not a function of earlier treatment events; that is, the sequential position of this treatment is not important. However, if a unit is not a first-order state, then it is known that the amount of treatment provided is determined, in part, by its position in a treatment sequence. (Reuter 1977, pp. 263-64).

Reuter develops a methodology for testing hypotheses of order, using analysis of variance (ANOVA) and chi-square tests of homogeneity. He acknowledges that his approach lacks a theoretical basis, and admits that this represents a limitation of his study.

Reuter validates his model by comparing its predictions of utilization to observed utilization over a 1-year period. He indicates that the predicted values agree with observed values within a range of experimental error, but he notes that more accurate projections of utilization might have been obtained had he used the number of visits to a service unit, rather than the number of days registered in the unit, as a measure of outpatient utilization.

Von Korff (1978) adapts an ergodic Markov chain to the life table to model the dynamics of the public mental hosital population. The combination of these two approaches results in a model that includes the "revolving door" phenomenon as an element. Using the model, Von Korff projects the steady-state census of patients aged 65 years or older at admission. By a sensitivity analysis of various parameters of the model, Von Korff demonstrates that reduction of the readmission rate of discharged patients is relatively ineffective in controlling the accumulation of long-stay patients in public mental hospitals. Similarly, reducing the admission rates to each facility increases the proportion of long-stay patients in such settings. The discharge rate of short-term patients is identified as a crucial control upon the rate of accumulation of long-stay patients.

Additional applications of Markovian models to studies of utilization can be found in the section on program evaluation (see Meredith 1974; Trinkl 1974). These studies focus on the evaluation of alternative programs or policies, but employ Markovian approaches to model their impact upon utilization of services.

Systems dynamics models have also been used to study utilization patterns of populations. Bernard et al. (1977) use a systems dynamics model

to simulate the distribution of services to mentally deficient children in Quebec. The model contains four types of environmental settings: Family placement (child lives at home and requires no services); special placement (child lives at home and receives home-based outpatient services); external placement (child receives institutional services on an outpatient basis); and internal placement (child is an institutional resident). Parameters of the model are initialized using data obtained from the Ministry of Social Affairs. Simulations using the model reveal the need for positive intervention to tranfer greater numbers of children from the internal placement to other placements, and they identify service gaps in the various environmental states.

5. Forecasting the Demand for Services: Psychiatric Bed Requirements

In a recent review of the literature on the estimation and projection of psychiatric bed needs through 1973, it was noted

> . . . That there is a relative scarcity of articles proposing or using statistical formulae for estimating psychiatric bed needs may be reflective of a certain amount of caution and circumspection on the part of planners (32).

The reviewer further notes that many of the 29 studies she reviewed ". . . are presented as if psychiatric bed needs exist in a vacuum" (33) rather than as a complement of the availability of other psychiatric services in a community. In this sense, the utilization models presented earlier can be seen to embody a more comprehensive approach to forecasting bed needs (see, for example, Reuter 1977).

Sweillam and Tardiff (1978) present a Markov model specifically designed to forecast psychiatric inpatient utilization for the State of New York. A potentially attractive aspect of this model is its capability for producing age-specific forecasts; these are aggregated in this article to produce forecasts for children, adolescents, adults, and the elderly. The model defines the resident population at any time as a function of new admissions, residents remaining in the previous age category, transfers (residents moving into a new age category), and discharges. Sweillam and Tardiff validated the model by testing its prediction of bed utilization for 1974-75 against observed utilization and showed a mean absolute error for all age groups of just over 0.4 percent in 1974 and 0.3% in 1975. Somewhat higher although still acceptable errors were obtained in predicting utilization by children and adolescents.

6. Summary

As noted earlier, there have been very few applications of operations research to the analysis of the need for mental health services. Recent applications of mathematical modeling to epidemiology in chronic disease (Mullooly and Oleinick 1975; Von Korff and Parker, 1980) suggest that such approaches may make valuable contributions to our understanding of psychiatric epidemiology.

Among the studies reviewed in this paper, no studies of mental health manpower productivity or program capacity were found. These are areas in which operations research may be expected to contribute in the future. Despite these gaps in the operations research analysis of mental health services systems, some novel measures of system performance emerge from the studies reviewed. Among these measures, we would include the diagnostic intensity parameter developed by Mullooly and Oleinick (1975), the process drift parameter discussed by Eaton and Whitmore (1977), and the uses of the hazard function described by Reuter and Von Korff (1980). Further work is needed with each of these measures to exploit more fully their utility for mental health services research.

An important contribution of operations research to mental health services research has been the formulation of length of stay as a stochastic process. At the present time, inpatient length of stay appears to be best characterized by mixed exponential, lognormal, and inverse Gaussian probabilistic models (Eaton and Whitmore 1977; Von Korff 1979).

Several issues remain to be resolved in using these models to describe the length of stay phenomenon. These issues include the choice of methods for fitting such models to the data and the selection of criteria to measure goodness-of-fit. (See Von Korff 1979 for a discussion of both issues.) Eaton and Whitmore (1977) discuss the problems of interpreting the findings of such models.

Further work needs to be done at the level of the community mental health center. Reuter and Von Korff (1980) have applied the Weibull model to CMHC data, but it is not clear whether this model is the most appropriate one to characterize length of stay for such facilities.

Markovian as well as systems dynamics models have been used to study utilization of mental health services. Such models can be used to identify existing patterns of care for various subpopulations (see Reuter 1977) and to forecast future utilization (see especially Sweillam and Tardiff 1978). Future applications of both types of models are highly likely.

One issue that needs to be addressed in future work is raised by Reuter (1977): To what extent can the use of such models be made routine within a mental health care facility? A second (and interrelated) issue is the determination of the level within the mental health services system for which such a "routinized" model would be most appropriate. Further work is necessary to resolve these issues.

C. Resource Allocation

1. Introduction

The published literature contains few examples of operations research approaches to resource allocation in the mental health services system. The scarcity of published work probably does not reflect the true level of operations research activity in this area. In the case of manpower studies, for example, Lyons (1975) points out that

> . . . in most States the central department of mental health has carried out overview studies of manpower needs in the State institutions which are not released to the public in the form of recognized publications in journals (22).

Lyons suggests that one possible reason for their reluctance to publish may be that

> . . . an individual hospital will undertake a study . . . to meet its needs of budget regulation, staff allocation, etc. However, since intuitive judgements are often used as fixed parameters, and a systematic model or framework for analysis is not developed, the studies are not considered valid in other settings and as a result are not published (pp. 22-23).

The studies reviewed in this section, then, should not be taken to represent the only operations research approaches to problems of resource allocation in mental health care. These studies should instead be viewed as illustrations of specific approaches to specific problems enountered by mental health care facilities.

The studies discussed here include a manpower and staffing model, a model for the selection of optimal training programs in a hospital for the mentally retarded, and financial planning models.

2. Mental Health Staffing in a State Hospital

In an overall review of general health operations research manpower models, Levine and Kahn (1975) state that

> . . . the benefits derived have been sketchy. Much work has been done in some areas, such as in scheduling and assignment, while in other areas little has been done. Many of the applications have been on small localized settings, thus severely limiting generalization of findings and methodology. Even where a considerable operations research effort has been expended, as in nursing manpower allocation, the conclusion has to be reached that operations research has had little direct effect on actual nursing management (p. 346).

They further point out that "viewed as a whole, the body of literature in the health manpower field appears as a fragmented and often disjointed series of studies. In many areas there is little continuity of development" (p. 343).

This is especially true of mental health manpower and staffing studies, where there is a dearth of published work. Lyons (1975) discusses this problem and attempts to relate his study of staffing patterns in a State hospital facility to some previous studies in the general health and health operations research literature. These latter studies (Bircher and Sarnato 1968; Binner and Halpern 1970; and Naleway 1970) were not available for inclusion in this review, but are listed in the resource allocation section of the annotated bibliography.

Lyons (1975) develops two models for the staffing problems within the State hospital. The first model describes the yearly staff allocation problem through an integer linear programing approach. The objective function in this model is maximization of the appropriateness of personnel for the provision of care, constrained by budget, clinical supervision requirements, and existing patient needs. The model produces a delineation of the optimum mix of personnel to be employed in a facility, based upon a measure of the appropriateness of each new or changed assignment of a patient to a therapist--an appropriateness index.

A second model also uses this appropriateness index as a criterion for optimization. This assignment-scheduling model can be used to assign tasks to therapists and to generate staff schedules for the facility. The objective function for this model maximizes this index for a planned therapeutic activity at a specific time. Constraints on the numbers of therapy activities and on the size of group therapy sessions are imposed on the model. In this model, the emphasis is on assigning and scheduling as many hours of the patients' therapy needs as is possible, given the limitations of staff availability and time. This model is also formulated as an integer linear programing model.

Lyons and Young (1976) present a more general formulation of the allocation model for application in large psychiatric hospital settings. They discuss the generalizability of the allocation model to other facilities, and specify six criteria that such facilities should meet for effective application of the model. The six criteria are as follows: The facility, unit, or ward must be a defined entity whose director has fiscal responsibility for evaluating the trade-off between appropriateness and cost of personnel types; the personnel working within the facility must be accountable to the administrator for a specified percentage of their time; classification of staff activities into mutually exclusive categories must be realistic in the specific setting; the operating policies of the particular setting must be reflected in the constraint equations; an appropriateness index must be developed for each new setting; and outpatient components require additional variables and constraints within the model.

Applications of the allocation model to settings other than psychiatric hospitals are currently being explored; for example, Morsicato and Lyons (1979) recently applied this model to a multimodality alcoholism treatment facility in New York.

3. Selection of Optimal Training Programs for Mentally Retarded Patients

Another type of resource allocation problem is represented by the selection of programs for a specific population. Meredith (1976) develops a stationary Markov chain model for use in a State hospital that offers a variety of programs for mentally retarded patients. The model is noteworthy in two respects. First, the model can be used in program evaluation to simulate alterations in policies or programs. A second, related advantage of this approach is the ability of the model to use values of cost, benefit, and net benefit as measures of performance.

Separate transition matrices are computed for each program (standard care, intensive training, behavior modification, day school, and foster placement). Patients' states are defined by a general ability index based upon clinician ratings. The probabilities of transition into each state, when combined with cost per patient per program, permit calculation of the benefits achieved from that program. Net benefit (benefit less cost) is used as a measure of performance.

The Markov program selection model seeks to maximize expected net benefits achieved from the various programs. The use of a discount factor applied to expected net benefits permits the simulation of various levels of future benefit and cost. The model can be used with cohorts of patients, and Meredith notes that efforts are currently under way to permit the use of the model to select programs for individual patients.

4. Financial Planning Models

The financing of mental health care represents a very important type of resource allocation problem. One approach to this problem at a statewide level is illustrated by Bodin et al. (1972). This project was conducted for the New York State Department of Mental Hygiene and the New York State Legislature. The primary goal of both the department and the legislature was to realine mental health care systems within the State so that diagnosis of the individual's need, and not economic considerations, would determine the nature of the care provided for treating the mentally ill.

The authors developed a simulation model that creates a State and local shared-funding formula serving this goal while minimizing the fiscal impact on each of the counties in the State. The model allocates a portion of the present local county expenditures to the costs of treating county patients in State institutions and allocates an increased portion of State expenditures to the costs of community operated programs. One of the simulated solutions was subsequently adopted by the State in legislation. Although political considerations required some modification of the model's optimal solution, the authors note that the most important aspects of the solution were passed in legislation.

Coleman et al. (1978) present a review of financial planning models for use in health care organizations. These models can be applied in inpatient and outpatient settings. Financial planning models vary in complexity, but most of the models cited by these authors combine a

capability to process a wide variety of accounting variables to generate routine financial reports with capability to simulate variations in these variables. They summarize current development in this area by noting that

> . . . financial managers and model builders have come a long way; however, they still have a long way to go but only a short time to get there. Although many health care organizations are still asking "what happened?" instead of "what if?", they are quickly learning that models have much to offer when one wants to study the probable effects of rate setting, cost reimbursement and budgetary decisions before they are implemented (p. 68).

5. Summary

Despite the paucity of published operations research approaches to resource allocation in mental health care, this area of activity has generally been a major focus for operations research in a variety of fields. As Lyons (1975) suggested, much of the actual operations research activity in resource allocation has been conducted at specific sites in the context of specific problems. As a result, many of the projects and studies have not found their way into publication, thereby making an assessment of the contributions of operations research to problems of resource allocation for mental health care a difficult task. Nonetheless, there have been some published applications in this area, notably in manpower and staffing allocation, the allocation of patients to programs, and fiscal planning.

Lyons's (1975) approach to staffing allocation uses an integer linear programing model to allocate staff to unitized wards in a State hospital. An appropriateness index, constructed by a modified Q-sort technique using hospital staff assessment of who should perform various therapeutic activities, is used as a criterion of optimality within the model. A more general formulation of the model is presented by Lyons and Young (1976), and the model is currently being applied in other settings. (See Morsicato and Lyons 1979.)

Levine and Kahn (1975) discuss the larger field of health manpower modeling and note the need for a "master plan" for operations research studies in this area. This appears especially valid for studies of mental health manpower, where the lack of measures of productivity and performance has hindered the development of a unified body of findings.

Meredith's (1976) stationary Markov chain model within the Pacific State Hospital appears to be a promising approach to determining an optimal program mix. An advantage of his approach lies in the ability of Markov chain models to include cost-benefit analyses as a model element. The use of discounted expected net benefit as a criterion of optimality represents an interesting approach to the allocation of patients to programs.

Further work is needed in this area, however. To an important extent, determination of the optimal allocation of programs to a geographic area relies heavily on the existence of reliable and valid measures of program effectiveness which can be used to compare types of programs. Although

cost-benefit and cost-effectiveness analysis represents one type of yardstick, other measures should be examined as well.

Bodin et al. (1972) demonstrate the utility of simulation in their evaluation of alternative State and local mental health funding formulas. It is difficult to determine whether more studies of this type will be conducted in the future, since so few examples emerge from the published literature.

At the mental health care organizational level, the Coleman et al. (1978) review of financial planning models deserves attention within the mental health community. The development and use of such models has emerged only within the 1970s. However, the capability to generate routine financial reports and to provide simulations enabling policymakers to explore the impact of cost reimbursement policies indicate that financial planning models may prove valuable to the mental health services field.

D. Author-Date References

1. The President's Commission on Mental Health Report to the President from the President's Commission on Mental Health. Vol. I. Washington, D.C.: Supt. of Docs., U.S. Govt. Print. Off., 1978, p. 49.

2. ADAMHA Workgroup on Epidemiology, Health Services Research and Statistics/Data Systems Epidemiology, Health Systems Research, and Statistics/Data Systems: Report of an ADAMHA Workgroup. Rockville: Alcohol, Drug Abuse, and Mental Health Administration, 1978.

3. Stimson, D.H., and Stimson, R.H. Operations Research in the Hospital: Diagnosis and Prognosis. Chicago: Health Research and Education Trust, 1972.

4. Shuman, L.J.; Speas, R.D.; Jr., and Young, J.P., eds. Operations Research in Health Care: A Critical Analysis. Baltimore: The Johns Hopkins University Press, 1975.

5. Fries, B.E. Bibliography of operations research in health-care systems. Operations Research, 24(5):801-814, 1976.

6. Fries, B.E. Bibliography of operations research in health care systems: An update. Operations Research, 27(2):408-419, 1979.

7. ORSA Ad Hoc Committee on Professional Standards. Guidelines for Professional Practice. Operations Research, 19(5):1127-1146, 1971. p. 1127-1128.

8. Churchman, C.W. Operations research as a profession. Management Science, 17(2):B37-B53, 1970. p. B-39.

9. Duncan, I.B., and Curnow, R.N. Operational research in the health and social services. Journal of the Royal Statistical Society, 141(2-A): 153-194, 1978. p. 154.

10. National Institute of Mental Health. An Administrator's Handbook on the Application of Operations Research to the Management of Mental Health Systems, by Halpert, H.P.; Horvath, W.J.; and Young, J.P. DHEW Pub. No. 1003. Washington, D.C.: Supt. of Docs., U.S. Govt. Print. Off., 1970. p. v.

11. Ackoff, R.L. The development of operations research as a science. Operations Research, 4(3):265-295, 1956.

12. Ackoff, R.L. Toward a strategy of operations research. In: Ackoff, R.L., ed. Progress in Operations Research. Vol I. New York: John Wiley & Sons, 1961. pp. 3-34.

13. Beer, S. Cybernetics and operations research. Operations Research Quarterly, 10:1-21, 1959. p. 16-17.

14. Bolling, W.B. Queuing model of a hospital emergency room. Industrial Engineering, 4(9):26-31, 1972.

15. Kao, E.P.C. A semi-Markov model to predict recovery progress of coronary patients. Health Services Research, 7:191-208, 1972.

16. Navarro, V. Planning personal health services: A Markovian model. Medical Care, 7:242-249, 1969.

17. Kolesar, P. A Markovian model for hospital admission scheduling. Management Science, 16:B384-B396, 1970.

18. Hirsch, G.B., and Miller, S. Evaluating H.M.O. policies with a computer simulation model. Medical Care, 12:668-681, 1974.

19. Hirsch, G.B., and Killingsworth, W.R. A new framework for projecting dental manpower requirements. Inquiry, 12:126-142, 1975.

20. Luckman, J., and Stringer, J. The operational research approach to problem solving. British Medical Bulletin, 30:257-261, 1974. p. 257.

21. Goldberg, E.S. Evaluation research and its utilization. In: Lieberman, E.J. ed. Mental Health: The Public Health Challenge. Washington, D.C.: American Public Health Association, 1975. p. 103.

22. See for example Ahmed, M.B., and Stein, D. PPBS in a community mental health center. Administration in Mental Health, 3(1):79-85, 1975.

23. Kilburg, R. General systems theory and community mental health: A view from the boiler room. International Journal of Mental Health, 5(4): 73-102, 1976-77.

24. Ibid., p. 82.

25. Forrester, J.W. Counterintuitive behavior of social systems. Technology Review, 73(3):52-68, 1971. p.54.

26. Ibid., p.54.

27. Bailey, N.T.J. The Elements of Stochastic Processes with Applications to the Natural Sciences, New York: John Wiley & Sons, 1964. p.2.

28. For a more in-depth discussion of dynamic programing, see Hillier, F.S., and Lieberman, G.J. Operations Research, San Francisco: Holden-Day Inc., 1974. Chapter 6, pp. 248-279.

29. Shuman, L.J., and Wolfe, H. Mathematical programming. In: Shuman, L.J.; Speas, R.D., Jr.; and Young, J.P., eds. Operations Research in Health Care: A Critical Analysis, Baltimore: The Johns Hopkins University Press, 1975. Chapter 9, p. 177.

30. See Kay, F.D., Jr. Application of social area analysis to program planning and evaluation. Journal of Evaluation and Program Planning, 1:65-78, 1978, for a more complete discussion of this approach.

31. National Institute of Mental Health. Series D No. 2, Psychiatric Bed Needs: An Analytic Review. DHEW Pub. No. (ADM) 79-205. Washington, D.C.: Supt. of Docs., U.S. Govt. Print. Off., 1979.

32. Ibid., p.6.

33. Ibid., p.5

ANNOTATED BIBLIOGRAPHY

A. Program Evaluation

Burgess, J.; Nelson, R.H.; and Walhaus, R. Network analysis as a method for the evaluation of service delivery systems. Community Mental Health Journal, 10(3):337-344, 1974.

This conceptual paper explores the application of network analysis to problems of patient flow through a network of community mental health services. Data on 302 patients receiving mental health services in an Illinois CMHC are used to characterize the service delivery system. Analysis focuses on the longest paths through the network; the presence of "cycles" (return paths within the network) is used as an indicator of ineffective service. Cases classified as most severe exhibited a high degree of cycling as did patients with one or more admissions to a State hospital.

Correa, H., and Sangl, J. Mathematical models for decision-making in planning drug abuse control programs. Socioeconomic Planning Sciences, 11(5):273-290, 1977.

This conceptual article reviews several mathematical programing models for drug abuse control. While the bulk of the article is directed toward planning, the models can be applied to the evaluation of policy alternatives in the treatment and control of drug abuse. Included are linear programing models, nonlinear models, a disaggregated linear model, a dynamic model, and a brief consideration of probability models. Data from several studies are presented; a review of the literature was used to provide estimates of key parameters in a number of examples. The authors emphasize that their conclusions should be interpreted with great caution due to the unreliability of their data, the simplicity of the examples presented, and the lack of a sufficient number of simulation runs conducted with these models.

Eyman, R.K.; Tarjan, G.; and McGunigle, D. The Markov chain as a method of evaluating schools for mentally retarded. American Journal of Mental Deficiency, 72(3):435-444, 1967.

This paper presents an empirical evaluation of the effectiveness a day school program versus "standard care" (conventional treatment) in Pacific State Hospital. Data were obtained for all first admissions of mentally retarded children to the hospital between July 1, 1958, and June 30, 1962 (1,367 patients). To further insure comparability, 97 day school patients were matched on chronological age and IQ with 97 standard care patients. Both groups were followed over a 4-year period. Analysis was conducted with a Markov chain model. By the end of the fourth year, more school patients than standard care patients had been released into the community. Change in status was most likely to occur by the third year after admission, if at all, and younger patients changed status most rapidly during the first 2 years of institutionalization.

Goldschmidt, P.G. A cost-effectiveness model for evaluating health care programs: Applications to drug abuse treatment. Inquiry, 13(1):29-47, 1976.

The author presents an overview and general summary of The Johns Hopkins University Interdrug Project (1972-73). The project consisted of an evaluation of 10 drug abuse treatment programs in various parts of the country. The focus in this article is on a comparison of two treatment regimens: methadone maintenance and therapeutic community. Effectiveness is measured in Effectiveness Measure Units (EMU), which are a combination of time in treatment and durability of treatment effect. The cost-effectiveness of each regimen is calculated over a 30-month period, and methadone maintenance was found to be about twice as cost-effective as the therapeutic community approach.

Guttentag, M. Subjectivity and its use in evaluation research. Evaluation, 1(2):60-65, 1973. And,

Guttentag, M., and Snapper, K. Plans, evaluations and decisions. Evaluation, 2(1):58-64; 73-74, 1974.

A description of the use of multiattribute utility theory within the Office of Child Development, DHEW, is given in these two articles. The technique permits decisionmakers to evaluate programs or alternative actions in terms of the extent to which they maximize important organizational values. A description of the methodology of multiattribute utility theory is presented in the first article. The second paper contains a demonstration of the application of the multiattribute utility theory in the selection of research projects for funding and of recommendations for broad programmatic strategies which OCD could pursue.

Haro, M.S. A systematic approach to evaluating mental health services. The Journal of School Health, 48(9):554-558, 1978.

The use of a simple input-output model for developing and evaluating mental health services in the educational system is presented. Collection of data on followup with teachers and parents, and the use of time-elapsed-in-system measures for evaluating the provision of routine mental health services, are discussed.

Hertzman, M., and Levin, G. Empirical confirmation of a simulation model of mental hospitalization. International Journal of Social Psychiatry, 20(3-4):218-224, 1974a.

The authors present the rationale, development, and results of the use of a systems dynamics model of mental hospitalization. They compare general hospital psychiatric and community mental health center wards with respect to emergency room visits, admissions, discharges, and relative staff morale over a 70-day period. Significant differences in admission patterns were

found over time: periodic declines in staff morale in the general psychiatric services result in patient discharges, which in turn lead to increased admissions and staff workloads resulting in further reduction in morale. This pattern was not observed in the community mental health centers.

Hertzman, M., and Levin, G. The uses of a macro-systems modelling approach to mental hospitalization. International Journal of Social Psychiatry, 20(3-4):225-230, 1974b.

The paper provides a general definition of the modeling process and its applicability to the mental hospitalization process. Examination of the general hospital admission rates over time suggested that these are not prompted solely by patient need for hospitalization, a finding that resulted in the performance of the first study.

Hertzman, M., and Montague, B. Cost-benefit analysis and alcoholism. Journal of Studies on Alcohol, 38(7):1371-1385, 1977.

This review article discusses the applications of cost-benefit analysis to the evaluation of alcoholism programs, noting the general contributions of the National Institute on Alcohol Abuse and Alcoholism in this area. The authors discuss the measurement of benefits derived from such programs and note the potential use of the Impairment Index from the Alcoholism Treatment Center Monitoring System as a validated instrument for the measurement of capability. The article reviews several cost-benefit studies on insurance benefit packages.

Hutcheson, B., and Krause, E. Systems analysis and mental health. Community Mental Health Journal, 5(1):29-45, 1969.

A descriptive introduction to systems analysis using an input-output model based on the work of W. Leontief is presented in this paper. Hypothetical data are used to illustrate the "inter-sector" approach taken by the authors. Two applications are described. The first divides the community into various sectors and uses the resultant table as a device for collating social indices and statistics. The second application uses time spent in each sector as a means of calculating an input coefficient matrix.

Levin, G., and Roberts, E.B. The Dynamics of Human Service Delivery. Cambridge: Ballinger Publishing Company, 1976. 275 pp.

This book presents three applications of systems dynamics models. One of these, described in chapters 4 and 5 and appendix A, is a simulation of a community mental health center developed to explore the treatment dropout phenomenon. The assumptions and variables of this model are specified in chapter 4, and simulations conducted with the model are detailed in chapter 5. Based on these simulations, the authors recommend that CMHCs invest resources in efforts to build up and maintain patients' expectations of

benefit from treatment. Appendix A presents the actual model in DYNAMO language. Other chapters present systems dynamics models of an educational classroom and a projection of dental care supply and demand.

Levin, G.; Hirsch, G.; and Roberts, E.B. Narcotics and the community: A system simulation. American Journal of Public Health, 62(6):861-873, 1972.

A system dynamics simulation of the narcotics problem in a community is presented in this paper. The model demonstrates that before an effective reduction in a narcotics problem in a community can take place, the problem must be defined by the community as a medical and social problem rather than as a law enforcement problem. When the problem has been so redefined, rehabilitation programs will be initiated. If such programs are begun before the community has come to acknowledge the medical aspects of the problem, these programs will be resisted by the community.

Levy, L.; Herzog, A.N.; and Slotkin, E.J. The evaluation of state-wide mental health programs - a systems approach. In: Cooke, P.E., ed. Community Psychology and Community Mental Health. San Francisco: Holden-Day, 1970. pp. 254-264.

The investigators present a very general description of a systems analytic approach to evaluation of a statewide mental health system (Illinois). A model is outlined in which the State is disaggregated into mental health planning areas subject to constraints: fixed population base, contiguity of area units, relative homogeneity of a number of social and demographic variables, and easy accessibility to existing health services to the population. A "mathematical grouping procedure" (unspecified) is employed to select community areas that satisfy the constraints and insure maximum homogeneity with respect to the large numbers of ecological variables. The model is not described.

Meredith, J. Program evaluation in a hospital for mentally retarded persons. American Journal of Mental Deficiency, 78:471-481, 1974.

The paper presents an empirical evaluation of four in-hospital programs (intensive training ward, behavior modification, day school and foster placement) versus "standard care" at Pacific State Hospital, California. Data were collected on a cohort of 615 profound and severely retarded (IQ less than 35) nonphysically handicapped children under age 15 years. An index of general abilities tapping eight self-help categories was developed to measure progress due to treatment. A stationary Markov chain was used to model the process of improvement over time. Transition matrices for each program were compared. Behavior modification did not generate a transition matrix significantly different from standard care. The more expensive programs (intensive training ward and day school) showed greater value in maintaining present ability levels than in promoting improvement of them. The author notes the capability of this approach to combine assessment of cost and benefit program aspects of such programs.

Mittenthal, S.D. A systems approach to human services integration. Evaluation, 3(1-2):142-148, 1976.

The author describes a systems analysis of the DHEW Services Integration Targets of Opportunity (SITO) program. This evaluation was descriptive and sought to assess the approximation of the SITO projects to models of an operating human services system. Because none of the projects began or subsequently instituted a needs-specification process, no data existed to permit assessment of the degree to which these projects reduced the amount and severity of need. Many SITO projects made inappropriate or suboptimal use of their information systems. Other findings demonstrated a range of variance in system governance, with more effective governance combining broad community representation and sufficient power and authority to set priorities, affect resource allocation, and provide visibility and legitimacy to developmental efforts. Few SITO projects provide sufficient documentation of client pathways through the system; the author notes that such documentation establishes functional validity and should serve as one measure of system effectiveness. Despite the importance of the system agent (case manager, broker, etc.), there was considerable variation in functions, roles, status, and accountability in the various projects. The author believes that despite general knowledge of physical and economic development, a corresponding knowledge of social service system development is lacking at present.

Muraco, W.A.; Vezner, K.O.; and King, J.A. Deconcentration of community mental health services under the constraint of concentrated geographic demand. Journal of the American Institute of Planners, 43(4):371-379, 1977.

The paper presents an empirical evaluation of a policy issue: the desirability of decentralizing mental health services in Lucas County, Ohio, (population 430,000). The authors take two approaches to the measurement of demand: comparison of demand indicators (number of patients per census tract released from the State hospital servicing the area, number of clients per tract served by the CMHC, and the number of clients per tract served by State and federally funded agencies), and social area analysis. Data were obtained on all client activity, by agency and home census tract for the period 1974-76. Demand was found to be geographically concentrated. The problem was then formulated as a multifacility constrained transport problem. Constraints were established to insure that each service center has equalized demand while maintaining a sufficiently high threshold (at least 500 clients per year) to support provision of services. An assignment algorithm was used to allocate service centers. It was found that decentralizing mental health service centers only minimally reduced client movement costs but appreciably increased system administrative costs. The authors note that further work is necessary to determine the generalizability of this finding for other medium-sized areas and that these results should not be generalized to large or small population centers.

Murrell, S.A. An open system model for psychotherapy evaluation. Community Mental Health Journal, 7(3):209-217, 1971.

The author presents a conceptual approach to evaluation of psychotherapy and patient change. Patient change is viewed as an interactive process between the patient-therapist system and the patient and his social system (family, friends). Change arises from the controlled introduction of negative feedback (information of a different sign than that present in the patient's social system) within a range of the patient's tolerance for this input. The author notes that this model relates concepts of social ecology, general systems theory, cybernetics, and information theory to the study of psychotherapy outcomes.

Ogurzsoff, S.; Pennock, M.; Sykes, S.; and Vogel-Sprott, M. Problem drinkers and treatment agencies in an urban community: A systems approach. Canadian Journal of Public Health, 67(3):232-236, 1976.

The authors describe a survey of nine agencies providing alcoholism treatment services in a southern Ontario community. Data from the survey were originally intended to be used to create a network flow model of the treatment network, but this phase of the project could not be completed because of data limitations. These limitations were the lack of standardized coding of individual patients among agencies, the lack of referral documentation, and the lack of standarized followup procedures. Analysis of collected data is presented and discussed.

Swint, J.M., and Nelson, W.B. The application of economic analysis to evaluation of alcoholism rehabilitation programs. Inquiry, 14(1)63-72, 1977.

This conceptual article applies cost-benefit analysis to the evaluation of a hypothetical alcoholism rehabilitation program. The authors' purpose is to demonstrate the use of this technique; calculations of various cost factors and benefits are presented in some detail.

Swint, J.M., and Nelson, W.B. Prospective evaluation of alcoholism rehabilitation efforts: The role of cost-benefit and cost-effectiveness analyses. Journal of Studies on Alcohol, 38(7):1386-1404, 1977.

This conceptual article discusses cost-benefit and cost-effectiveness analysis from the point of view of the types of information afforded by these techniques. The authors discuss the limitations of each approach and illustrate their utility in the evaluation of alcoholism rehabilitation programs by means of three hypothetical examples. They conclude that cost-benefit analysis permits the comparison of programs with different objectives and permits evaluation of the objective itself, while cost-effectiveness analysis permits comparison among programs with identical objectives.

Trinkl, F.H. A stochastic analysis of programs for the mentally retarded. Operations Research, 22:1175-1191, 1974.

An empirical evaluation is made in this paper of the effects of proposed budgetary changes upon programs for the mentally retarded adult in Hawaii. Five program options were considered: The existing service system; accelerated community placements and expanded activity centers; extended sheltered workshops; a combination of accelerated community placements, expanded activity centers, and extended sheltered workshops; and a single placement, evaluation, and purchase-of-service system geared toward normalization. A value ranking procedure was used to weigh patterns of movement among transition states. Constraints were imposed in the form of penalty costs incurred for service gaps or too few service resources. The combination of cost analysis and achievable value obtained from the value-weighted Markov chain resulted in a recommendation for the fifth alternative (purchase-of-service system).

Votey, H.L., Jr., and Phillips, L. Minimizing the social costs of drug abuse: An economic analysis of alternatives for policy. Policy Sciences, 7(3):315-336, 1976.

The authors develop an analytical model of heroin demand, supply, and market control which minimizes the social cost of heroin abuse. Social cost is defined as a function of social and economic costs per offense in heroin-related crime, costs of heroin use per user (including loss of output, pain and suffering to addict and family, and costs of treatment), costs of corruption of public officials, costs of loss of personal freedom to incarcerated addicts, costs of law enforcement activities, and general social cost to society for losses incurred by the maintenance of a policy of preventive detention of addicts and suppliers. The resultant model is used to simulate three alternative policies: Restricting supply in the illicit market, restricting demand in the illicit market, and eliminating the illicit market through substitution of a legitimate source of heroin which undercuts the illicit supply. The model is used in a heuristic manner to focus findings from the general drug abuse control literature. Of the three alternatives, the undercutting of the illicit market by providing a legitimate source of heroin appears to incur the lowest social costs.

Wolpert, J., and Wolpert, E.R. The relocation of released mental hospital patients into residential communities. Policy Sciences, 7(1):31-51, 1976.

The authors present a general discussion of the policy of deinstitutionalization and its impact on the mental health system and the community, noting the lack, in many cases, of suitable after-care programs and the tendency of many released hospital patients to relocate in inner-city areas. They present a general assignment model that could be used to evaluate this process. The model is developed conceptually and uses

the number of favorable treatment outcomes as its objective function. The authors note that this model would require data that are not widely available (e.g., precise determination of outcome by defined classes of treatment modalities). The authors envision the model as a heuristic device for identifying high priority informational needs and for providing a structure for analysis of the effects of deinstitutionalization at the present time.

B. Analysis of Need and Demand for Mental Health Care

Bernard, J.C.; Camirand, F.; Hosios, A.J.; and Rousseau, J.M. Experi-Mental: A simulation of the distribution of services to mentally deficient children. Behavioral Science, 22(5):356-366, 1977.

An empirical simulation of several potential policy and program changes in the Quebec Ministry of Social Affair's programs for mentally deficient children. A systems dynamics model is developed that includes incidence and demographic data, mean IQ, mean physical health status, mean Social Quotient, and services offered by the Ministry. The model contains four states: Family placement, an internal state, (institutional placement), external state (receives institutional services on an outpatient basis), and a special state (home-based outpatient services). The effect of existing programs in altering the flow of children from state to state is explored. Several simulations revealed the need for positive intervention to transfer targeted numbers of children from the internal state to the other states and a need for expanded domestic services in the special environment. The authors noted that the project was so successful that an operations research staff was established within the ministry. This staff currently maintains an active involvement in modeling other social service systems for the ministry.

Eaton, W.W., and Whitmore, G.A. Length of stay as a stochastic process: A general approach and application to hospitalization for schizophrenia. Journal of Mathematical Sociology, 5:273-292, 1977.

This article presents a thorough review and comparison of life table and stochastic models of the length of stay (LOS) in hospitalization for schizophrenia. A discussion of the life table approach is presented, followed by a formulation of length of stay as a stochastic process. The models explored in this paper include the life table approach, exponential model, mixed exponential model, the Pearson type XI model, Weibull model, gamma model, lognormal model, and the inverse Gaussian model. Each model is fitted to data on 2,311 schizophrenic patients taken from the Maryland Psychiatric Case Register between the years 1961 and 1968. The goodness-of-fit of each model is tested by the maximum absolute deviation of the estimated distribution from the observed distribution. The authors conclude that the lognormal and inverse Gaussian models demonstrate the best fit. The inverse Gaussian model is preferred because of its attractive statistical characteristics. The authors note that it could be usefully thought of as a normative model of LOS.

Fox, P.D., and Kraemer, H.C. A probability model for the remission rate of discharged psychiatric patients. Management Science, 17(10):B694-B699, 1971.

The authors note that the cumulative proportion of discharged psychiatric patients rehospitalized one or more times at various time intervals is frequently used as a measure of effectiveness of psychiatric hospital treatment. The application of stochastic models of this process is explored and two such models are fitted to data from a mental hospital

facility which followed the readmission of patients over an 18-month period. The models utilize the mixed exponential distribution with a mean, u, which varies as a gamma distribution. In model I, the patients are all assumed to require rehospitalization at some point in time, while in model II, a proportion of the patient population is assumed never to require rehospitalization. Both models are fitted to the data by the maximum likelihood method. A likelihood ratio test of the two models indicated no significant difference between the models at the 5 percent level; however, model I was observed to fit the data better in earlier time periods, and model II fit better in later time periods to rehospitalization.

Hanson, B.L. A statistical model for length of stay in a mental hospital. Health Services Research, 8(1):37-45, 1973.

The use of a lognormal function to describe duration of psychiatric hospitalization is illustrated by applications to several sets of data: a cohort of 935 patients admitted to Haverford State Hospital in 1964 (followed for 12 months); cohorts of all hospital admissions from Central Hospital, Warwick, England, from 1883 to 1892 and of all released patients in 1954; and four cohorts from Philadelphia State Hospital, including all admissions during July 1963, March and July 1969, March and April 1970, and a random sample of 1966 admissions. In each case, the model was fitted by the least-squares technique, in which observed cumulative percentage releases are converted to their corresponding z scores; these are used to calculate expected z scores, which are then regressed on the natural log of time. The author concludes that the lognormal distribution function accounted satisfactorily for most of the data tested. He found some variation in goodness-of-fit across institutional settings, and noted that diagnostic category, treating institutions, and cohort all influenced release parameters.

Harrington, M.B. Forecasting areawide demand for health care services: A critical review of major techniques and their application. Inquiry, 14:254-268, 1977.

This is a general review of the uses of forecasting techniques to predict the demand (the amount of services actually used by individuals in a community) for health care services. The author notes that, although forecasting techniques have gradually gained in sophistication, the problems of large-scale public systems have increased in complexity as well. The author is concerned with feasible forecasting; that is, forecasts both useful and within the capabilities and budgets of health planners. To further define the notion of feasible forecasting, the author receives and compares six forecasting approaches (historical analogies, Delphic techniques, trend extrapolation, morphological analysis, computer simulations, and decision theory approaches), noting the strengths and weaknesses of each. He then creates a table, listing types of problems by forecasting technique and assessing the validity and precision of each forecasting approach. The author concludes that existing techniques can provide "fairly long term" forecasts effectively. The use of forecasting to

improve quality and cost control is likely to be less effective, because most methods are not geared to forecast demand for two or more services simultaneously, and most methods do not focus on the appropriateness of utilization.

Jantsch, E. Forecasting and the system approach: A critical survey. Policy Sciences, 3:475-498, 1972.

This is a general review of forecasting for and in social systems (including economics, urban and regional planning, technological forecasting, education, and health care). The author asserts that long-range planning in such contexts implies investment in a dynamic situation; forecasting is the prediction of outcomes of potential alternative investments and courses of action. The author receives techniques commonly used in each of the above social systems. He notes that the health care approach has introduced a heavy bias toward sequential problem solving, and argues that forecasting in health care has often resisted the use of quantitative approaches. There is an extensive bibliography (70 references).

MacStravic, R.E. Inpatient bed needs for psychiatric care. Administration in Mental Health, 5(1):14-20, 1977.

A central problem in forecasting demand for psychiatric inpatient beds is variability in demand. The author notes that performance by facilities is too often measured entirely in terms of occupancy levels, and that this measure fails to adequately deal with variability in demand. He proposes a linear regression equation based upon the logarithm of the average census, which describes expected peak census. This approach is tested on data from a survey of 25 hospitals in Virginia. The formula came within 1 bed of predicting the peak census for 13 of the 15 hospitals. An additional finding of this study is that an 85 percent occupancy standard for psychiatric inpatient facilities seems a legitimate expectation only for units comprising more than 250 beds. The author recommends his technique as a supplement to occupancy standards.

Mullooly, J.P., and Oleinick, A. A dynamic model of prevalence for an epidemiologic study of a chronic disease within a health maintenance organization. Journal of Chronic Diseases, 28:317-340, 1975.

An empirical study of the relationship between source prevalence and treated prevalence rates of chronic allergic disease (asthma, hayfever, etc.) within the Kaiser Health Plan. Data were generated from the computerized utilization records of a 5 percent sample of KHP members for the years 1967-71. A system of differential equations that model the relationships of immigration rate (joining the plan), emigration rate (leaving the plan), diagnosis rate, remission rate, and time to treated prevalence (cumulative) are used to estimate source prevalence. The model is tested on data from KHP and on data from Tecumseh, Michigan, where survey data on source prevalence existed. The authors conclude that the agreement between actual prevalence rates and equilibrium source prevalence rates as specified by the model are fairly good.

Pollack, E.S., and Taube, C.A. Trends and projections in state hospital use. In: Zusman, J., and Bertsch, E.F., eds. The Future Role of the State Hospital, Lexington: Lexington Books, 1973. pp. 31-58.

The authors provide a general overview and discussion of trends in admission, readmission, and discharges from State mental hospitals in the United States, based on annual data from the national reporting program of the National Institute of Mental Health. Three trend lines are fitted to data on the numbers of resident patients by age and major diagnostic category for the years 1961-70; these trend lines are used to project 1971 data. The trend lines include a linear trend, a linear trend fitted to logarithms of the observation, and a quadratic formula (not specified in the article). The quadratic line provides the best fit to the data over the 10-year period and provides the best estimates for 1971 and 1972 values. The authors suggest that this implies that the annual percentage change in number of resident patients follows a straight line downward.

Reuter, J.A. "Semi-Markov model of utilization in a multi-service mental health treatment facility." Unpublished doctoral dissertation, School of Hygiene and Public Health, The Johns Hopkins University, 1977. 293 pp.

The author notes that traditional approaches to studies of mental health services utilization often fail to account for the sequential, dynamic process of utilization and the interdependency of mental health service subsystems. One approach that does take these aspects into account is provided by a class of models, called semi-Markov chains, describing the flow of patients between these subsystems.

The development and application of a semi-Markov chain model to an evaluation of the equity of services among whites and blacks is described using data from the Connecticut Mental Health Center. The author describes the development and use of a methodology for testing the extent to which assumptions of the order of states in such models are violated, based upon chi-square tests of homogeneity and the estimation of ANOVA models. He notes that at present, this methodology has no theoretical basis (it does not constitute a necessary and sufficient test of the order of a semi-Markov state). He validated the model by comparing its predictions of utilization for a 1-year period (July 1, 1973, to June 30, 1974). In its evaluation application, the model was used to identify residual differences between the utilization patterns of whites and blacks after controlling for some differences in need. The author acknowledges limitations in this aspect of his research, such as the exclusion of certain important variables (i.e, socioeconomic status) from the variable set used to define "needs." The author concludes by noting that semi-Markov chain models represent a methodological approach to the study of utilization which should be generalizable to a variety of health and mental health settings; however, he cautions that the use of such models should not, at present, be attempted by institutions that do not have access to individuals with advanced mathematical and statistical training who could serve as consultants.

Reuter, J.A., and Von Korff, M. The distribution of length of stay and the accumulation of chronic patients in a mental health center. Administration in Mental Health, 7(3):187-199, 1980.

The paper presents an empirical study of the distribution of length of stay in a mental health center and some of its characteristics. Data were collected on the length of stay of 123 inpatients in a mental health center serving a catchment area of about 100,000 persons over a 3-month period in 1973. A computer simulation of inpatient length of stay is estimated from the Weibull model, selected because one of its parameters (the discharge rate of persons who have remained in treatment for X time periods) is particularly sensitive to increases and decreases in the distribution's hazard functions. It is noted that the hazard function decreases in this sample with increasing length of stay. The authors point out that one of the characteristics of the hazard function is that it can be used to predict the proportion of the future census of a facility which is composed of chronic, long-stay patients. As a result of the computer simulations, the authors conclude that the slope of the hazard function is a stronger predictor of the eventual size of the long-stay population than the more traditionally employed indicator of average length of stay. They also note that accumulation of long-stay patients tends toward a steady-state equilibrium, and that systems characteristized by a decreasing hazard function require longer periods of time to reach equilibrium than do facilities with increasing hazard functions. Some implications of these findings for mental health planning and administration are addressed.

Revelle, C.; Feldman, F.; and Lynn, W. An optimization model of tuberculosis epidemiology. Management Science, 16(4):B-190-B-211, 1969.

A linear programing optimization model is applied to the management and control of tuberculosis. The model minimizes the total cost of attaining a predetermined desired reduction pattern of active cases of tuberculosis subject to constraints on the numbers of vaccinations administered and costs. Hypothetical data are used to illustrate the application of the model in evaluating four strategies, starting from an initial condition of 22,000 active cases. Strategy 1 targets a decrease in active cases to 14,000 at 12 years and a sharp decrease to 2,000 actives at 20 years. Strategy 2 is a linear reduction by 1,000 active cases per year to 2,000 actives at year 20. Strategy 3 promotes an initial decrease to 9,600 actives by year 8 and a slower decrease to 2,000 by year 20. Strategy 4 reduces the active cases to 7,200 at year 6, and then a more gradual reduction to 2,000 by year 20. Solution of the differential equations in the model reveals that strategies 3 and 4, while more costly, are to be preferred because they represent fewer man-years of tuberculosis and a lower potential for later spread because of the presence of fewer nonactive cases.

Sweillam, A., and Tardiff, K. Prediction of psychiatric inpatient utilization: A Markov chain model. Administration in Mental Health, 6(2): 161-173, 1978.

The investigators describe the development and validation of a Markov chain model for predicting psychiatric inpatient utilization in New York. The model uses data on new admissions and discharges by age group (broken out as children, adolescents, adults, and elderly, but age cutoff points are not specified in the article). The resident population (workload) is thus a function of new admissions, residents remaining in previous age category, and transfer (residents moving into a new age category), and discharges. The model is validated by testing its prediction of bed utilization for 1974 and 1975 against observed utilization for those years. The model showed a mean absolute percent error for all age groups of 0.42 in 1974 and 0.39 for 1975. Higher errors were found in predicting utilization by children and adolescents, although these errors were within the acceptable range.

Von Korff, M. "The dynamics of the public mental hospital population of Dutchess County, New York, 1964-1970." Unpublished doctoral dissertation, School of Hygiene and Public Health, The Johns Hopkins University, 1978. 293 pp.

The author notes that the planning of mental health services for the severely mentally ill requires organized population data on the size and composition of populations using such services and the patterns of their use of services over time. A model involving life table methodology is developed; the mixed exponential distribution is found to be a valid probability model of length of stay. The use of this approach, and its ability to project the steady-census for patients aged 65 or older at admission, permits a model of the mental hospital population to be constructed that includes the revolving door phenomenon. This model is then applied to data on public mental hospital admissions from Dutchess County, New York, during the years 1964-70. The author finds that reductions of readmission rates of discharged patients are relatively ineffective in controlling the accumulation of long-stay patients in this setting. A transient effect of reducing admission rates to public mental hospitals is an increase in the long-stay proportion of the mental hospital population. The discharge rate of short-stay patients is identified as a crucial control of the rate of accumulation of long-stay patients. The author concludes that a policy of easy discharge and easy readmission represent an effective policy in the administration of mental hospital facilities.

Von Korff, M. A statistical model of the duration of mental hospitalization: the mixed exponential distribution. Journal of Mathematical Sociology, 6:169-175, 1979.

The author, responding to a paper by Eaton and Whitmore (1977) notes that a problem encountered in using their criterion of goodness-of-fit (maximum absolute deviation of the predicted cumulative distribution from

the observed distribution) is that, for the various models tested, this criterion is insensitive to the poor fit in the tail of a skewed distribution. He further notes that the procedure used by Eaton and Whitmore were inefficient. The author re-examines the mixed exponential model, refitting it by means of the maximum likelihood method to the Maryland Psychiatric Case Register data used in the Eaton and Whitmore study. Goodness-of-fit is tested by the Eaton and Whitmore criterion and by chi-square analysis, which the author argues provides a more stringent test in large samples. The mixed exponential is found to be comparable in its fit to the data to both the lognormal and inverse Gaussian models; however, the author concludes, none of the three models can be regarded as a natural law of LOS for this sample.

Von Korff, M., and Parker, R.C. The dynamics of the prevalence of chronic episodic disease. Journal of Chronic Diseases, 33(2):79-85, 1980.

This conceptual paper argues that the general epidemiologic equation prevalence equals incidence times average duration is not appropriate for diseases that run an episodic course. Using the life table, the authors formulate the Lifetime Sickday Proportion, equal to incidence times average episode duration times average number of episodes. They model the average episode duration through the mixed exponential distribution and the average number of episodes by the geometric distribution. Data from Dutchess County, New York, patients admitted with a diagnosis of schizophrenia to State hospitals, 1964-65, are used to test the validity of these models. The authors conclude that the assumptions required by the use of these models may not obtain in practice, and that the models should be used preferably as heuristic devices for characterizing the dynamics of chronic episodic diseases.

C. Resource Allocation

Bodin, L.D.; Carroll, T.O.; Lee, A.; and Stout, S. Financing mental-health services in the State of New York. Operations Research, 20:942-954, 1972. And,

Bodin, L.D., and Carroll, T.O. Financing mental health services in the State of New York. An update. Operations Research, 22:292-294, 1974.

These articles represent a report on a project conducted for the New York State Legislature and the Department of Mental Hygiene. The project objective was to construct a shared State and local funding formula for the State of New York so that diagnosis of individual patient's need, and not economic considerations, would determine the nature of the care provided. The formula to be developed should minimize the fiscal impact of this policy shift on each of the counties of the State. A simulation model was constructed using aggregate data supplied by the Department of Mental Hygiene. The optimal solution derived from the model consisted of a per capita credit allocated to counties, based on the population of the county. Under this plan, a portion of the present local county expenditures is allocated to the costs of treating county patients residing in State institutions, while an increased portion of State expenditures is allocated to the costs of community-operated programs.

Coleman, J.R.; Kaminsky, F.C.; and McGee, F. A survey of financial planning models for health care organizations. Journal of Medical Systems, 2(1):59-69, 1978.

This review article assesses the state of the art of financial planning models for use in health care organizations. These models have developed during the past 10 years and have their origins in mathematical programing, statistical analysis, simulation, and computer modeling. The authors note that the models can be applied in inpatient and outpatient settings. Most of the article discusses and compares the more sophisticated financial models. These generally share a capability for analysis of a large number of accounting variables, generation of routine and special financial reports, and simulation of alteration in fiscal variables. The authors conclude that the ability of such models to facilitate the study of the impacts of rate setting, cost reimbursement, and budgetary decisions will encourage more widespread utilization of financial planning models in the future. The article lists 32 references.

Levine, E., and Kahn, H.D. Health manpower models. In: Shuman, L.J.; Speas, R.D.; and Young, J.P., eds. Operations Research in Health Care: A Critical Analysis, Baltimore: The Johns Hopkins University Press, 1975. pp. 337-364.

This review of the general health operations research literature in health manpower modeling explores the historical development of operations research efforts in this area. The authors categorize operations research studies in terms of rationalizing task assignments, simplifying work,

substituting capital for labor, improving work scheduling, reducing time spent in movement, improving the organization of patient care services, improving the skills and knowledge of health manpower, improving supervision, and improving the administrative climate. The authors note that studies in health manpower have been fragmented and disjointed, in part, because of problems of design, funding, limitations in scope, and an inadequate attention to psychosocial factors in conceptualizing work behavior. They recommend the formulation of a master plan for operations research study of health manpower, which emphasizes study design and linkage of current findings to past results. Mental health manpower is not discussed. The article contains 121 citations.

Lyons, J.P. "Staffing Models for a Unitized Mental Hospital." Unpublished doctoral dissertation, School of Hygiene and Public Health, The Johns Hopkins University, 1975. 251 pp.

The author develops and applies two manpower staffing models in a geographically unitized State mental hospital setting. Within this hospital, separate parallel autonomous wards are maintained for distinct geographic regions serviced by the hospital. A staffing allocation model is constructed using an integer linear programing format. An appropriateness index constructed from a modified Q-sort technique applied to staff assessment of the appropriateness of various therapeutic activities for various levels of staff is used to formulate an objective function that maximizes the appropriateness of personnel for provision of patient care. The objective function is constrained by facility budget, clinical supervision requirements, and existing patient needs. The model generates on optimal mix of personnel to be employed within the facility. A second model assigns patients to therapists and schedules therapeutic activities for patients and staff, using the integer linear programing approach in combination with the appropriateness index.

The allocation model is the more successful of the two models according to the author. The author notes that the assignment-scheduling model did not adequately account for all the criteria by which clinicians actually made patient assignments to therapeutic activities. The author also notes that the use of the model requires the existence of a manual or computerized reporting system. The solution of the model (by branch and bound algorithm for mixed integer problems) also required the use of a computer facility, limiting the generalizability of the model to those facilities possessing computer equipment.

Lyons, J.P., and Young, J.P. A staff allocation model for mental health facilities. Health Services Research, 11(1):53-68, 1976.

The paper presents a more general discussion of the staff allocation model noted in Lyons (1975). In addition to a discussion of the model and the results of its application in a State mental hospital, the generalizability of the model to other mental health settings is discussed. Six criteria for such settings are described. Additional discussion of the implementation of the model is included and suggestions for its use are outlined.

Meredith, J. Selecting optimal training programs in a hospital for the mentally retarded. Operations Research, 24(5):899-915, 1976.

The author describes the development of a stationary Markov chain model for optimizing the discounted expected net benefit of alternative placements of cohorts of mentally retarded patients in Pacific State Hospital. The states of the Markov chain are defined by general ability levels based on clinician ratings. Transition probability matrices are derived for each of five programs (standard care, behavior modification, intensive training, day school, and home placement) run by or through the hospital. Costs per patient per program type are combined with the transition matrices to generate expected benefit. Net expected benefit is then obtained by subtracting cost from expected benefit and is used as a performance measure for the programs. A discount parameter applied to expected net benefit permits adjustment of the model for varying degrees of future benefit. The model can also be used as a tool in program evaluation. The author notes that work is currently in process to modify the model for use in selecting the optimal program for individual patients.

Morsicato, R., and Lyons, J.P. "A Staff Allocation Model Applied in a Multimodal Alcoholism Facility." Paper presented at the Joint National Meeting of T.I.M.S./O.R.S.A., New Orleans, April 30-May 2, 1979.

This paper describes an application of the staff allocation model described in Lyons (1975) to a multimodality alcoholism treatment facility. It was unavailable for review.

Binner, P., and Halpern, J. "Workforce Estimating and Analysis." Unpublished Fort Logan Research Paper, Fort Logan Mental Center, Denver, 1970.

Bircher, K., and Sarnato, H.K. "A Study of Staffing Patterns in Psychiatric Nursing." St. Elizabeth's Hospital, Washington, D.C., U.S. Government Printing Office, 1968.

Naleway, M. "Staffing Care of Patients Effectively, SCOPE: A Study of Pennsylvania's Mental Hospitals." Pennsylvania Office of Mental Health, Harrisburg, Pennsylvania, September 1970.

These three papers represent early efforts in mental health manpower. They were unavailable for review.

D. Miscellaneous Published Articles

Burgess, J.H. Operations research in mental health administration. Administration in Mental Health, 1:63-67, 1974.

The author presents a general discussion of operations research applied to the program of reducing readmission to State mental hospitals. A graph of "months to readmission" is displayed based on data from 384 patients readmitted to State hospitals between July 1, 1970 and June 30, 1971. The graph shows that the highest incidence of readmission occurs during the first 3 months following release and steadily declines after that. The author argues that sustaining-care programs should be able to obtain their greatest payoff during the first 3 months after discharge, and discusses the implications of this position for the continued monitoring of such patients by CMHCs.

Datel, W.E., and Murphy, J.G. A service-integrating model for deinstitutionalization. Administration in Mental Health, 2:35-45, 1975.

The authors outline the service integration for deinstitutionalization (SID) model, described as a systematic services integrating procedure for the orderly deinstitutionalization of residents of Virginia institutions for the mentally ill, mentally retarded, and juvenile offender populations in Virginia. Five structural components (assessment and prescription team, field staff of broker advocators, quality control team, automated information system, and committees of commissioners) integrate a variety of social services for the institutionalized populations. A lack of community resources to meet placement prescriptions is viewed as the primary factor in the large discrepancy between the numbers of clients prescribed for community placement and those actually placed in the community.

Finlay, D.G. Alcoholism and systems theory: Building a better mousetrap. Psychiatry, 42(3):272-278, 1978.

The author applies general behavior systems theory (GBST) to the problem of willingness of alcoholics to modify behavior. In a brief review, he makes the point that problem drinkers are better treatment prospects when they are actively involved in a social system. Problem drinkers are unlikely to seek help until they experience a state of crisis, which is often brought about as the result of pressure from the role network. The maintenance of crisis-level anxiety appears necessary to sustain the drinker's motivation for treatment. GBST thus views alcoholism as a problem in social interaction. A brief discussion of the assumptions, definitions, and postulates of GBST is presented and its application to strategies for treatment and intervention is discussed.

Galanter, M.; Karasu, T.B.; and Wilder, J.F. Alcohol and drug abuse consultation in the general hospital: A systems approach. American Journal of Psychiatry, 133(8):930-934, 1976.

The authors described a systems intervention within a general hospital setting directed at redefining medical treatment for addicted and alcoholic patients. At the outset of the study, treatment was provided only for the sequelae of addiction, partly as a result of the management problems that hospital staff experienced in working with alcoholic and addicted patients. The authors sought to introduce a social disease model to hospital staff through the provision of a consultation service staffed by a psychiatrist and three addiction counselors. The consultation service provided a referral system for the patients and educated hospital staff about drug and alcohol addition. This resulted in the gradual expansion of the hospital staff's medical model of patient care to include "social diseases."

Goldmeier, J., and Alexander, C.A. General systems and PERT concepts in community mental health planning. Maryland State Medical Journal, 24:46-50, 1975.

The authors discuss the use of PERT (critical path) methodology in planning a community mental health center. In this approach, the activities required to complete the project are identified, tasks necessary for the completion of subsequent tasks are noted, and tasks that can be undertaken concurrently receive attention to encourage coordination. PERT permits the estimation of optimistic time (shortest possible time needed to achieve a task) and pessimistic time (the longest possible amount of time needed to accomplish a task), thus facilitating task scheduling. The authors conclude that the application of PERT methodology to the planning of a community mental health center seemed to be especially useful and pertinent.

Greist, J.H.; Gustafson, D.H.; Stauss, F.F.; Rowse, G.L.; Laughren, T.P.; and Chiles, J.A. A computer interview for suicide-risk prediction. American Journal of Psychiatry, 130(12):1327-1332, 1973. And,

Gustafson, D.H.; Greist, J.H.; Stauss, F.F.; Erdman H.; and Laughren, T. A probabilistic system for identifying suicide attemptors. Computers and Biomedical Research, 10(2):83-89, 1977.

Both articles discuss the development of a computerized assessment procedure for the prediction of suicide risk within 3 months. The data processing model employs a Bayesian probability model to calculate likelihood of suicide attempt given the presence of various risk factors. Risk factors were derived from estimates made by the clinical staff from the Department of Psychiatry, University of Wisconsin-Madison. The first paper describes a test of the computer interview with 22 patients who had expressed suicidal ideas during their initial interviews at the clinic. Acceptance of the computer interview was high, especially among suicidal

patients. A second test, using subjects who had made attempts after their initial interviews and subjects who had not, revealed that the computer interview was more accurate in predicting suicide attempts than were the clinicians (70 percent versus 40 percent) and slightly less accurate in identifying nonattempts (90 percent versus 94 percent). The second article is slightly more technically oriented and presents a brief discussion of the effects of using unequal prior probabilities versus equal prior probabilities in the Bayesian analysis, and summarizes current research efforts with the computerized assessment technique.

Hayes-Roth, F.; Longabaugh, R.; and Ryback, R. Mental health: Systems and non-systems. International Journal of Mental Health, 5(4):5-31, 1977.

The authors note that the delivery of mental health care in the United States faces several problems, including inefficient and undesirable distributions of tasks, minimal control and planning, and maladaptive organization. They present a broad overview of systems analysis, which facilitates rational choice, as a method of approaching these problems. The authors discuss the mental hospital as a system to illustrate various system analysis concepts. One of the key concepts introduced is the management information system. The management information system ideally provides the overall system with information concerning the effects of its decisions (feedback), which the system can use to control its processes. One example of a management information system which provides this capability is the Problem Oriented Medical Record (POMR) system. The role of this system in facilitating utilization review is discussed.

Hedlund, J.L., and Hickman, C.V. Computers in mental health: A national survey. Journal of Mental Health Administration, 6(1):30-52, 1977.

The investigators report the results of a 1976 survey of departments of mental health of all 50 States and all independent mental health facilities known or suspected by the authors to have mental health information system projects (n = 40 departments of mental health responding). The authors report that over 70 percent of the State departments of mental health utilize computer support for administrative and clerical functions, with additional types of utilization (program evaluation, utilization review) planned in many States. Although the use of the computer in clinical applications is not great at present, the authors suggest that this function should increase in the future.

Henderson, P.B.; Magussen, M.G.; Snyderman, B.B.; and Homann, J. A clinical decision-making model for child psychiatric intervention selection. Psychological Reports, 37:923-934, 1975.

The paper describes a theoretical, four-component model that could be used as the basis for the design and operation of an automated data system. This system is presently in development at the Pittsburgh Child Guidance Center. The first component consists of the various treatment modalities

available within the center. The second component includes the clinical variables in the presenting problem which are necessary to select an option from the first component. The third component consists of variables derived from a careful externalization and explication of the clinicians' theoretical assumptions that underlie the varieties of treatment made available through the center. A fourth component includes the actual clinical information variables that will be studied and evaluated in the clinical assessment. The goal is to define a system of variables that will provide the minimum but sufficient degree of information necessary to select appropriate psychiatric interventions for children.

Honigfeld, G.; Klein, D.F.; and Feldman, S. Prediction of psychopharmacologic effect in man: Development and validation of a computerized diagnostic decision tree. Computers and Biomedical Research, 2(4):350-361, 1969. And,

Klein, D.F.; Honigfeld, G.; and Feldman, S. Prediction of drug effect in personality disorders. Journal of Nervous and Mental Disease, 156(3): 183-197, 1973.

These two papers present related studies on the effects of chlorpromazine and imipramine on patients of various diagnostic types. Patients were classified into various types by the use of a sequential diagnostic decision tree in which the ratio of true positives to false positives for each trait is maximized at every fork in the tree. The first paper compares this classification method with discriminant function analysis using as criteria two groups of patients clinically diagnosed as either excited or retarded and a 35-item standard interviewing rating scale. Both procedures were equally effective. The diagnostic decision tree was then applied to an undifferentiated pool of 336 patients and the results compared with earlier results from a drug study with mixed results for the computerized decision tree. The second study extends the use of the decision tree to personality disorders. In this study, the decision tree is again compared with clinician diagnoses and obtains an accuracy of 70 percent. Drug effectiveness by diagnostic category is discussed.

Kilburg, R. General systems theory and community mental health: A view from the boiler room. International Journal of Mental Health, 5(4):73-102, 1977.

The author reviews the concepts of general systems theory and provides an overview of applications in the mental health literature. While general systems theory provides a foundation for many community mental health activities, the author notes his inability to locate published data on the actual implementation of general systems theory in the daily operations of the various levels of the mental health system. He then describes three such levels (Federal, State and local) and discusses the ways in which general systems theory could be applied within an average community mental health center. The article contains an extensive bibliography of general systems theory/mental health literature (76 references).

Linkenhoker, D.D., and McCarron, L.T. Computerized assessment programming (CAP): A prescriptive strategy for delinquents. Behavioral Science, 19(4):254-259, 1974.

The authors note that juvenile delinquents frequently prove to be a diagnostic and treatment problem for both the criminal justice and mental health systems. The authors describe the development and application of an individualized, automated assessment program for such persons. The program consists of a diagnostic output level, a diagnostic statement level, and a remedial statement level. In addition to diagnostic assessment, the program generates remedial statements specifying appropriate behavior modification interventions to be undertaken by parents, teachers, and correctional staff. The system is programed in Fortran IV. Future applications in program evaluation studies are discussed.

McKeown, P.G.; Conocenti, P.; and Flannigan, J. PERT in patient placement. Administration in Mental Health, 4(2):83-89, 1977.

The application of PERT methodology to the deinstitutionalization of mental hospital patients is discussed in this paper. The process of community placement was broken down into specific tasks. The authors used a Delphi method to obtain from social workers and hospital staff estimates of the shortest possible time, most likely time, and longest possible time for task completion. This permitted identification of the critical path (the path on which delays in task completion would delay the entire process). Subsequently, the placement process was modeled by type of placement. The authors discuss some of the limitations of this approach (lack of hard data for determining completion times, lack of a clear-cut method used in placing patients) and note that their experiences in conducting this pilot study point out the need for efficient and standardized techniques such as PERT.

Messick, J.W.; Singh, A.J.; and May, P.R.A. A system analysis approach to planned change in a clinical psychiatric program. Journal of Psychiatric Nursing and Mental Health Services, 13(4):7-11, 1975.

The system analysis approach applied to staff overload and patient-flow problems encountered in a general psychiatric unit offering inpatient and outpatient services is described in this paper. The major thrust of the analysis focused on paperwork requirements, which were about to expand with the opening of a satellite outpatient facility. A systems study was made of processing and decisionmaking events involved in each outpatient visit, including direct observation of preparatory activities before the patient arrived and of activities involved in the patient's entry into, passage through, and exit from the outpatient system. Several types of problems were identified, including clerical and record keeping problems, unsuitable office space and traffic flow patterns, and misplaced records. A new storage system was designed and implemented and clerical office layout was redesigned, facilitating patient flow and record retrieval.

Morf, M.E., and Krane, W.R. Computers in behavioral science: A strategy for developing automated assessment systems. Behavioral Science, 18(4):294-306, 1973.

This paper reviews literature pertaining to the design of automated assessment systems, noting that the 1973 state of the art is rudimentary despite the sophistication of the mathematical procedures and computer hardware available for application to this area. The authors present a two-stage strategy designed to produce viable automated assessment procedures. They note that a diagnostic system requires two components: A set of personality dimensions, categories, or types, and a method of assigning new cases to the correct location on a dimension or to the correct category or type. The authors review several approaches relevant to determining dimensions and categories, and recommend an approach based upon an algorithm proposed by Carlson, who defined type as a cluster of cases, each of which is more like any other member of the cluster than like any nonmember. Assignment of new cases to the defined types is accomplished through discriminant function analysis and Bayesian nonsequential classification procedures. Limitations of these two techniques are discussed. The article contains an extensive bibliography of papers and empirical studies in automated assessment technique (56 references).

Roberts, B. A look at psychiatric decision making. American Journal of Psychiatry, 135(11):1384-1387, 1978.

This paper discusses the use of the decision table in psychiatric assessment. The decision table is presented as a sophisticated form of algorithm that can logically link variables with outputs in a compact manner. As presented here, the decision table consists of variables (conditions) and outputs (actions) listed along the left side of the table with the presence or absence of the condition (and indication of action to be taken) noted in the cells to the right. The various conditions are listed sequentially such that each condition narrows the range of actions over the preceding condition. The clinician thus enters the table at the top left and progressively works through the conditions in the table to arrive at an appropriate intervention. Several examples are presented, and the article contains a number of references in which this approach is explored in specific settings (33 references).

Speer, D.C.; Barnes, K.; Bloch, J.P.; Clark, C.; Eichel, E.; Franz, S.; and Weiskopf, R. Self-study within a social system: A system analysis of a community mental health center. Journal of Mental Health Administration, 5(2):46-59, 1976-77.

The authors describe an empirical study of staff dissatisfaction in a community mental health center serving a five-county catchment area in Indiana. The system (defined as the CMHC) had expanded its staff size tenfold in less than 3 years; a tension had developed between the developmental pressures toward greater specialization and the differentiation of roles and staff values favoring autonomy and general role latitude.

The authors constructed a questionnaire that focused on demographic variables, perception of agency assets and problems, and service location. Following administration of the questionnaire to the staff, the results were analyzed from the perspective of breadth of influence and responsibility. The empirical methodology was then abandoned and recommendations based on the problem areas cited in the study were formulated and presented to administrators and to the staff as a whole. The authors emphasize that their major purpose was not to conduct a study per se, but to formulate recommendations aimed at improving the overall level of systems support experienced by staff members; in this regard they argue that they were highly successful.

E. Author Index to Annotations

Alexander, C.A., 57

Barnes, K., 61
Bernard, J.C., 46
Bertsch, E.F., 49
Binner, P., 55
Bircher, K., 55
Bloch, J.P., 61
Bodin, L.D., 53
Burgess, J.H., 38, 56

Camirand, F., 46
Carroll, T.O., 53
Chiles, J.A., 57
Clark, C., 61
Coleman, J.R., 53
Conocenti, P., 60
Cooke, P.E., 41
Correa, H., 38

Datel, W.E., 56

Eaton, W.W., 46
Eichel, E., 61
Erdman, H., 57
Eyman, K.K. 38

Feldman, F., 50
Feldman, S., 59
Finlay, D.G., 56
Flannigan, J., 60
Fox P.D., 46
Franz, S., 61

Galanter, M., 57
Goldmeier, J., 57
Goldschmidt, P.G., 39
Greist, J.H., 57
Gustafson, D.H., 57
Guttentag, M., 39

Halpern,J., 55
Hanson, B.L., 47
Haro, M.S., 39
Harrington, M.B., 47
Hayes-Roth, F., 58
Hedlund, J.L., 58
Henderson, P.B., 58
Hertzman, M. 39, 40
Herzog, A.N., 41
Hickman, C.V., 58
Hirsch, G., 41
Homann,J., 58
Honigfeld, G., 59
Hosios, A.J., 46
Hutcheson, B., 40

Jantsch, E., 48

Kahn, H.D., 53
Kaminsky, F.C., 53
Karasu, T. B., 57
Kilburg, R., 59
King, J.A., 42
Klein, D.F., 59
Kraemer, H.C., 46
Krane, W.R., 61
Krause, E., 40

Langhren, T.P., 57
Lee, A., 53
Levin G., 39, 40, 41
Levine, E., 53
Levy, L., 41
Linkenhoker, D.D., 60
Longabaugh, R., 58
Lynn, W., 50
Lyons, J.P., 54, 55

MacStravic, R.E., 48
Magussen, M.G., 58
May, P.R.A., 60
McCarron, L.T., 60
McGee, F., 53
McGunigle, D., 38
McKeown, P.G., 60
Meredith, J., 41, 55
Messick, J.W., 60
Mittenthal, S.D., 42
Morf, M.E., 61
Mullooly, J.P., 48
Muraco, W.A., 42
Murphy, J.G., 56
Murrell, S.A., 43
Morsicato, R., 55
Montague, B.,40

Naleway, M., 55
Nelson, R.H., 38
Nelson, W.B., 43

Ogurzsoff, S., 43
Oleinick, A., 48

Parker, R.C., 52
Pennock, M., 43
Phillips, L., 44
Pollack, E.S., 49

Reuter, J.A., 49, 50
Revelle, C., 50
Roberts, B., 61
Robert, E.B., 40, 41
Rousseau, J.M., 46
Rowse, G.L., 57
Ryback, R., 58

Sangl, J., 38
Sarnato, H.K., 55
Shuman, L.J., 53
Singh, A.J., 60
Slotkin, E.J., 41
Snapper, K., 39
Snyderman, B.B., 58
Speas, R.D., 53
Speer, D.C., 61
Stauss, F.F., 57
Stout, S., 53
Sweillam, A., 51
Swint, J.M., 43
Sykes, S., 43

Tardiff, K., 51
Tarjan, G., 38
Taube, C.A., 49
Trinkl, F.H., 44

Vezner, K.O., 42
Vogel-Sprott, M., 43
Von Korff, M., 50, 51, 52
Votey, H.L., Jr., 44

Walnaus, R., 38
Weiskopf, R., 61
Whitmore, C.A., 46
Wilder, J.F., 57
Wolpert, E.R., 44
Wolpert, J., 44

Young, J.P., 53, 54

Zusman, J., 49

☆U.S. GOVERNMENT PRINTING OFFICE: 1981-341-166/6314